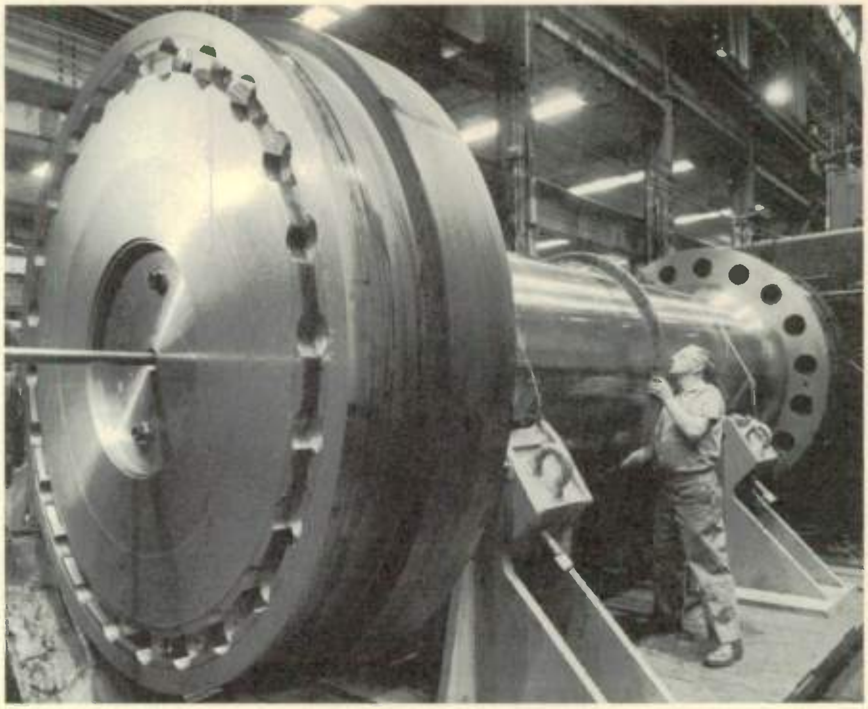
WESTINGHOUSE Engineer

JULY 1959

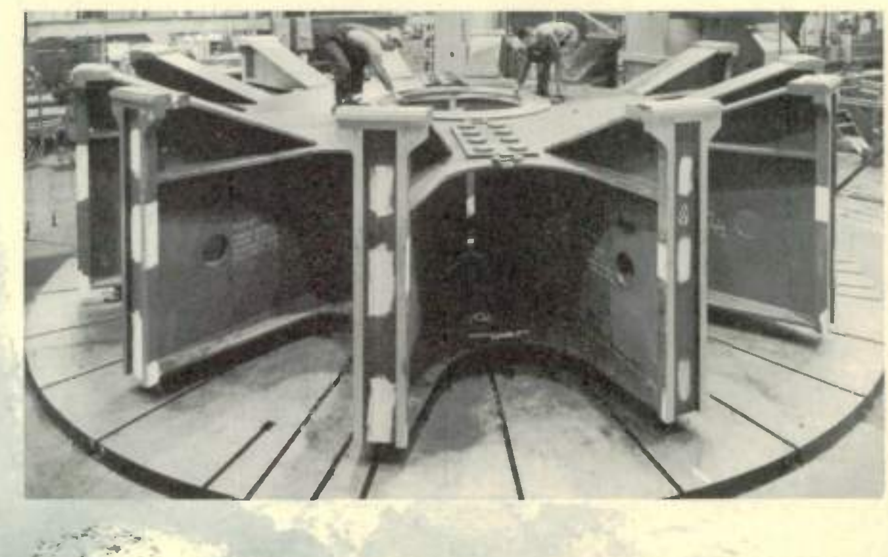


FIRST WATERWHEEL GENERATOR FOR NIAGARA PROJECT NEARING COMPLETION

The first of thirteen 167 000-kva waterwheel generators for the $720 million New York State Authority's Niagara power project is near completion.

With a maximum installed capacity of 1 950 000 kilowatts at the main generating plant, the Niagara project will be the largest hydroelectric project east of the Mississippi River and the second largest in the United States. Only Grand Coulee in Washington State has a greater capacity.

Shipment of the parts for only one of the 120-rpm generators, not including the waterwheel, will require 34 railroad cars. Installation of the first unit is scheduled to begin early in 1960. Westinghouse will ship the last of the thirteen umbrella-type waterwheel generators early in 1961. **(Above)** This 50-ton shaft will be shipped to the project site at Lewiston, N.Y. when operations on the 96-inch engine lathe are completed. The shank diameter of the shaft is 50 inches. **(Below)** Craftsmen who operate the 40-foot boring mill are checking dimensions of the "spider." The "spider" is 27 feet in diameter and weighs 50 tons.



COVER DESIGN: A modular design and the use of high-quality manufacturing techniques have given great versatility to a new line of helical gear units called Moduline. Cover artist Dick Marsh forms this month's cover design from several of these Moduline components.

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Published bimonthly (January, March, May, July, September, and November) by Westinghouse Electric Corporation, Pittsburgh, Pa.

SUBSCRIPTIONS: Annual subscription price in the United States and possessions is $2.50; in Canada, $3.00; other countries, $3.00. Single copy, 50¢. Address all communications to *Westinghouse* ENGINEER, P.O. Box 2278, 3 Gateway Center, Pittsburgh 30, Pa.

INDEXING AND MICROFILM: *Westinghouse* ENGINEER contents are regularly indexed in Industrial Arts Index. Reproductions of the magazine by years are available on positive microfilm from University Microfilms, 313 N. First Street, Ann Arbor, Michigan.

THE WESTINGHOUSE ENGINEER IS PRINTED IN THE UNITED STATES BY THE LAKESIDE PRESS, CHICAGO, ILLINOIS

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Cypak, K-Dar, Moduline, Slipsyn, Dynetric

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ADVANCE DEVELOPMENTS IN COMPONENT DESIGN FOR LARGE STEAM TURBINES

H. R. REESE, Manager
Advance Design Section
Large Turbine Engineering
Westinghouse Electric Corporation
Philadelphia, Pennsylvania

Advance development of components for large steam turbines will permit better manufacturing reliability, pave the way for greater engineering research, and help satisfy the requirements of expected growth of the electric utility industry.

Traditionally, steam turbines have been almost completely "custom engineered" for each specific application. Frequently this applies to individual components, as well as the overall turbine arrangement.

At this stage of increasing complexity of turbine design, however, a better approach is possible through the *advanced* development of components and associated turbine equipment. By using the considerable experience available in turbine design and operation, and carefully factoring in trends in the electric utility industry, engineers can "pre-engineer" components with many attendant benefits. Among the advantages are greater flexibility of turbine arrangement, improved components, and greater manufacturing reliability.

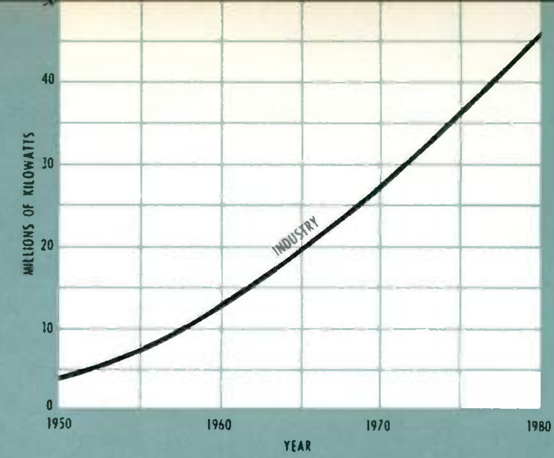


Fig. 1 Projected gross yearly additions to the electric utility industry.

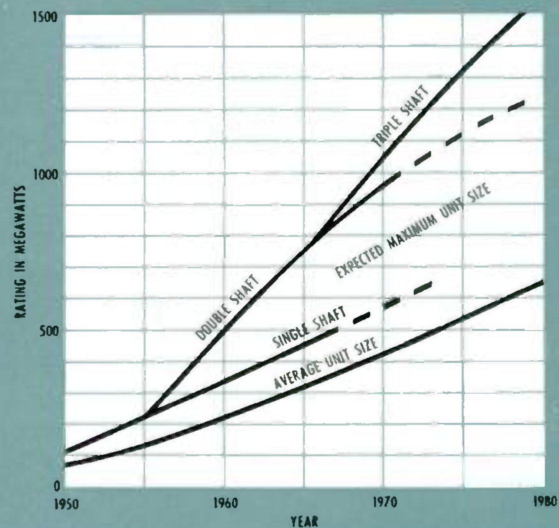


Fig. 2 Projected unit sizes.

trends

The trends and forecasts for the utility industry must be studied in planning the development of turbine components and facilities. For example, the projected national figure for kilowatts installed per year (Fig. 1) influences the projected average and maximum unit sizes (Fig. 2). The present *average* size is approximately 200 mw, and is expected to increase 200 mw every ten years to approximately 600 mw in 1978. The *maximum* size of a single-shaft unit is presently 325 mw, and is expected to reach 500 mw by 1967. The rating of the single-shaft unit may be extended to 650 mw by 1973 if the development of longer 3600-rpm last-row blades follows past trends. Double-shaft units are presently built in capacities of 450 and 500 mw, and are expected to reach 1000 mw by 1971, with a possibility of 1250 mw by 1980. Triple-shaft units may enter the picture for ratings of 800 mw in 1966 and grow to a maximum of 1500 mw by 1978. Economics will influence the rate at which the maximum sizes are developed.

The types of 3600- and 1800-rpm elements are shown in Fig. 5. The arrangement of these elements making up a line of 3600-rpm units and 3600/1800-rpm units are shown in Figs. 6 and 7 respectively. The number of elements for each arrangement varies from two for the tandem-compound double-flow unit to eight for the cross-compound octuple-flow unit. Note that the number of elements is increasing at a rate of approximately fifty percent every ten years.

The trends in pressure, temperatures, and ratings are shown in Fig. 4. This demonstrates the fundamental principle of increasing steam conditions as ratings are increased, which maintains a reasonable ratio of leakage to volumetric flow.

For smaller units, pressures of 1450 and 1800 psig prevail, with inlet temperatures of 1000 degrees F and reheat temperatures of 1000 degrees F. The larger ratings generally operate at pressures of 2400 psig, with preference for 2000 psig for some installations. Steam inlet temperatures are generally 1000 to 1050 degrees F, with reheat temperatures of 1000 and 1050 degrees F. Units ranging from 500 to 750 mw are expected to have inlet conditions of 3500 psig and 1050 degrees F, with single and double reheat of 1050 degrees F. Units above 750 mw will probably operate at the more advanced steam conditions of 5000 to 6000 psig and 1100 to 1200 degrees F with reheat temperatures of 1050 degrees F.

complex number for design

The single- and two-cylinder non-reheat units of the past were much easier to design and manufacture than the present reheat turbines. The change in effort required can be evaluated by a *complex number*. The complex number shown in Fig. 3 represents the total effort required to engineer and manufacture the turbine mix. The unity base for the complex number is the effort required to develop and produce the conventional non-reheat single-cylinder and tandem-compound turbines that were installed about 1946.

The curve shows that this complex number is doubling approximately every ten years. Combining the increasing complex number and the increasing number of elements indicates that the total effort is tripling every ten years.

Although this summary of effort is an estimate, the trend should be recognized and met with a well-planned design program. The program should include interchangeability of basic elements among the turbine arrangements, and a more uniform heat-balance arrangement to cover average conditions. More uniform plant design practice would be helpful in the overall program.

advance developments of turbine components

In setting up the basic pre-engineered elements and components, stress has been placed on the overall application to the turbine arrangements shown in Figs. 6 and 7. The individual basic elements that make up the 3600-rpm and 3600/1800-rpm machines are illustrated schematically in Fig. 5. Common coding is used in Figs. 5, 6, and 7 to illustrate the duplication of basic elements.

The arrangements of 3600-rpm turbine elements are made up from seven basic 3600-rpm pre-engineered elements (Fig. 5). These pre-engineered machine components can be assembled in almost any combination for inlet steam conditions up to 2400 psig, 1050 degrees F with reheat to 1000 degrees F. Machines of increased rating are produced by adding high pressure and temperature front ends to the multiplicity of elements that made up the three basic arrangements.

For ratings of 600 to 750 mw, inlet steam conditions of 3500 psig, 1050 degrees F may become desirable. For example, such a turbine could be a cross-compound, sextuple-flow machine (Fig. 6), which could consist of two triple-exhaust machines, the high-pressure shaft headed by very-high-pressure elements, and the intermediate-pressure shaft headed by the basic intermediate-pressure elements.

The cross-compound octuple-flow arrangement (Fig. 6) suggests even higher inlet steam conditions. Perhaps pressures of 5000 to 6000 psig and temperatures up to 1200 degrees F would prove economical. This machine consists of two tandem-compound, quadruple-flow machines with a super-pressure element on one shaft and a high-pressure element on the other. The sextuple- or octuple-flow arrangement could support ratings up to 750 and 1000 kw respectively, should they prove economical.

interchangeability of basic elements

In turbine arrangements, the same basic elements often are repeated in the various combinations. For example, the split opposed-flow high-pressure element is used five times in Figs. 6 and 7; the 3600-rpm double-flow low-pressure element is used at least once in every turbine arrangement in Fig. 6. By considering the requirements of turbine arrangements collectively, flexibility can be designed into each basic element.

In establishing a line of basic elements, there are three major considerations: (1) range of steam conditions; (2) range of turbine ratings; and (3) turbine arrangements in which the elements will be used.

Evaluation of these requirements collectively shows that

Model of tandem-compound, quadruple-flow turbine.

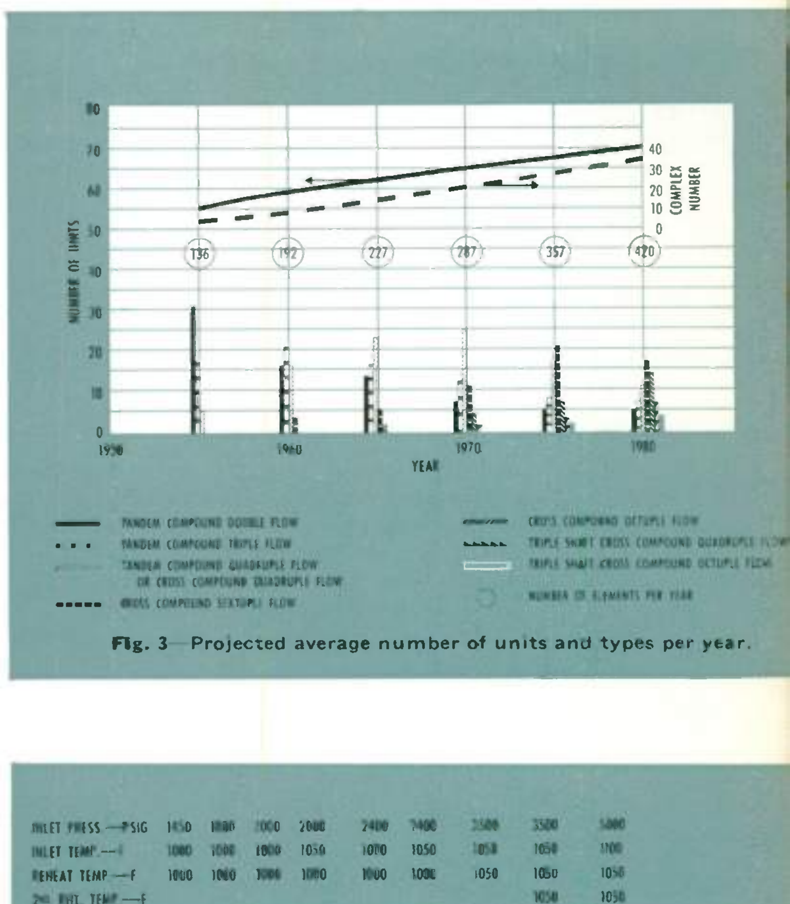


Fig. 3—Projected average number of units and types per year.

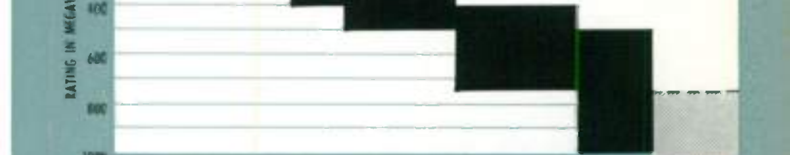


Fig. 4—Preferred steam conditions.

duplicate sets of major castings, including outer and inner cylinders, nozzle chambers, and gland cases can be used. A single composite spindle forging can act as a back-up for any one of a number of units. The manufacturing advantages of this situation are obvious, making possible shorter and more reliable delivery schedules.

An example of an element that has been given the full treatment is the high-pressure turbine element. This element has been designed for a range of steam conditions from 1800 psig, 1000 degrees F to 2400 psig, 1050 degrees F, for use in turbines rated from 175 mw through 325 mw. The element can be used in tandem-compound triple-flow, tandem and cross-compound quadruple-flow, and cross-compound double-flow 3600/1800-rpm machine arrangements.

The consideration given to this high-pressure element is typical. This same philosophy is being applied to all basic elements. The 3600-rpm low-pressure turbine provides a tremendous potential for duplication. Designs for these elements are nearing completion. They are not an adaptation of existing elements to form an integrated line of low-pressure turbines, but represent a new design based on the latest advancements. Air-flow-model studies have been carried out in the development laboratory to support the program. These experimental studies have been directed at all portions of the turbine through which steam flows. Such portions include entrances to the turbine casings, where a transition from pipe flow to an annular flow occurs, and the exhaust hood.

In pre-engineering low-pressure turbines, designers have obtained duplication in more than the basic elements (turbine rotor and stator). In many instances, other component parts can be duplicated. For example, the low-pressure cylinder covers for the machine shown in Fig. 6, with the exception of the single-flow ends used in the triple- and sextuple-flow machine, are exact duplicates. The generator end bases are duplicates on all of the machines in Fig. 6.

advanced design features in future machines

As a result of progress made in mechanical and thermodynamic design programs, turbine designers have been able to proceed with design layouts of 3600-rpm turbine elements using a new 28-inch last-row blade. Designers plan to adapt the 28-inch low-pressure elements to all the turbines shown in Fig. 6. This is a simple substitution for the tandem-compound, double- and quadruple-flow units. However, each turbine arrangement must be given complete design analysis to determine its feasibility. For example, the higher ratings associated with the 28-inch end make questionable (from a mechanical adequacy standpoint) the practicality of building the intermediate-pressure, low-pressure element used in the triple-exhaust turbine. This particular element is currently under study.

advance developments of associated components

Such associated components as throttle valves, steam chests, interceptor valves, oil reservoirs, pedestals, and control systems can be pre-engineered in the same fashion as the turbine elements. For example, a study of throttle valve and steam chest sizes for reheat turbines ranging up to 325 mw revealed that only four sizes were needed. By holding dimensions of all the major parts fixed, the throttle valve and steam chest body forgings can be prestocked, providing a continuous flow of back-up forgings for critical parts.

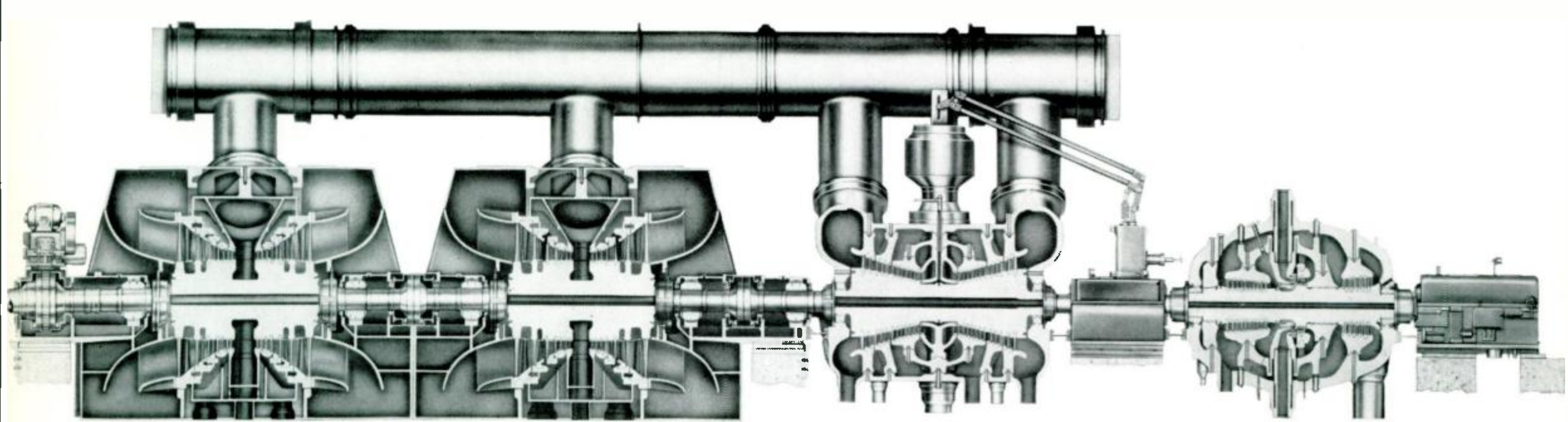
A typical example of a preplanned component is the oil reservoir. Three reservoir sizes were selected for turbines ranging from 50 to 400 mw. To coordinate these designs, the height and width of the reservoirs are held constant; a change in size or capacity is made by varying length. Because dimensions were standardized, many duplications are possible in the details, such as plate size, oil-pump supports, oil piping, oil-cooler supports, and general hardware. Designers have also endeavored to incorporate a maximum of flexibility in the location of the reservoir and seal oil unit. This flexibility is obtained by altering the lengths of straight pipes only.

Another important area of this program is the advance planning of equipment drawings needed for plant layout work. These drawings include oil piping, turbine outlines, and unit wiring diagrams.

summary

Pre-engineered turbine components represent a major addition to development programs on metallurgy, thermodynamics, and mechanical design features. The primary purpose of the program is to develop turbine components that will permit arrangements to accommodate the wide range of turbine applications existing in the industry at present, and for the foreseeable future.

Pre-engineering will help meet the ever growing needs of the electric utility industry in an orderly manner. Through acceptance and use of the program, technical and manufacturing facilities and manpower can be used more effectively to obtain more efficient production schedules and better manufacturing reliability. ■



Tandem-compound quadruple-flow reheat turbine.

Fig. 5—3600-RPM TURBINE ELEMENTS

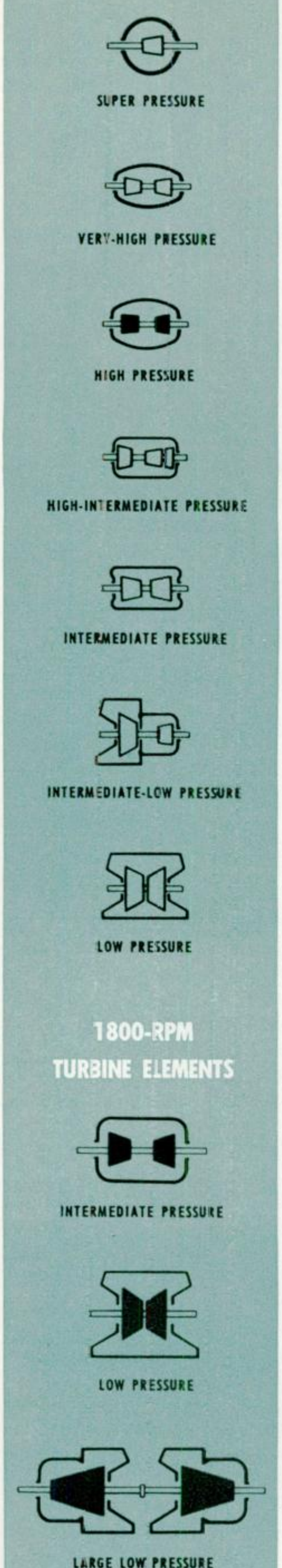


Fig. 6—ARRANGEMENT OF 3600-RPM TURBINE ELEMENTS

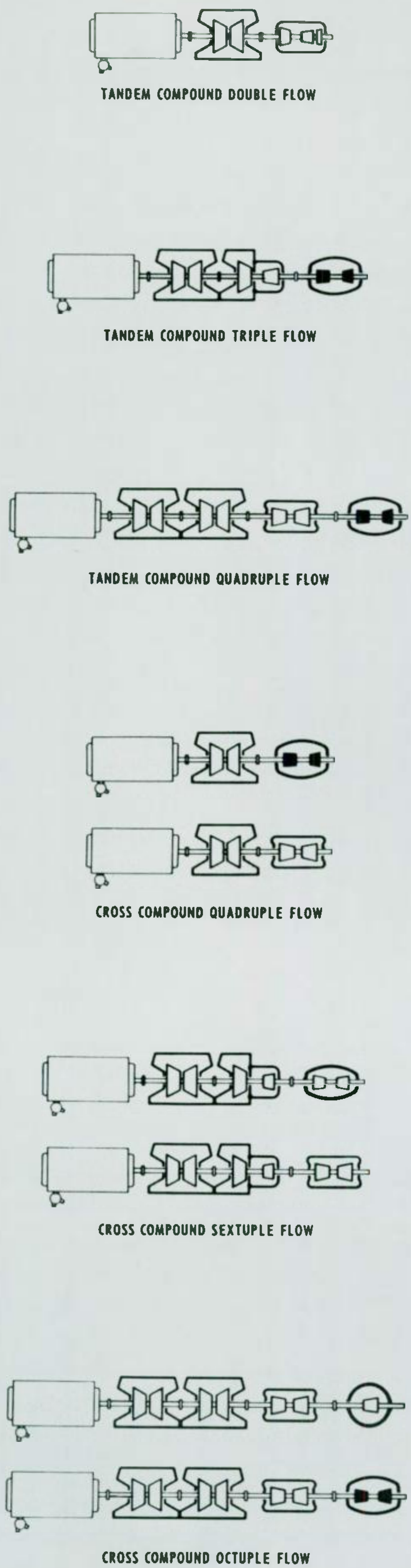
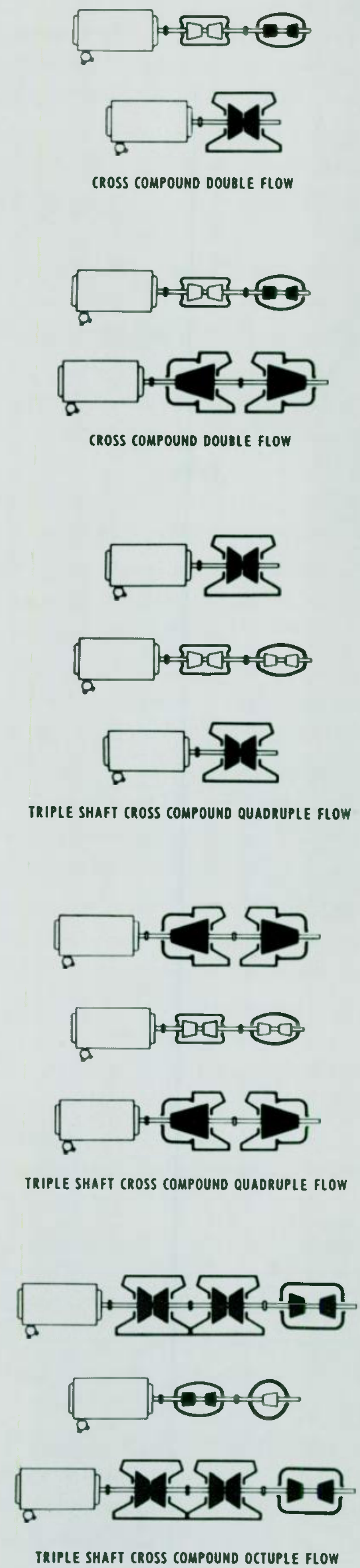


Fig. 7—ARRANGEMENT OF 3600/1800-RPM TURBINE ELEMENTS



The Project Manager . . . his role in advanced technology industry

PAUL O. GADDIS
Westinghouse Electric Corporation
Pittsburgh, Pennsylvania

The desirable characteristics for a manager depend in part on what kind of a group he must manage. Herewith are some views on the requirements for the manager of an advanced-technology project.

Organization by project—the welding together of various talents to achieve a specific, tangible goal in a limited time—is a familiar and oft-used technique. In technical development, the project frequently consists of scientific, engineering, manufacturing, and supporting personnel, and is intended to achieve a relatively short-term goal. The increasing complexity of modern technology, however, and the increasingly common necessity of working at the frontiers of scientific knowledge have resulted in a new type of project—the so-called *advanced technology project*. With this has come the need for a new type of manager, with the necessary skills to meet the unusual challenges involved.

This new breed of manager is easy to identify in rapidly growing new fields, such as electronics, astronautics, and nucleonics. Generally, his project's goal is to create an advanced product, and most often this is a product requiring a large measure of technical pioneering. The primary tool available to him is the brainpower of professional specialists in diverse fields; he uses this tool in all phases of the creation of his product, from concept through initial test operation and manufacturing stages.

Several other characteristics help distinguish the advanced technology project: Its success frequently requires rapid conversion of the most recent discoveries of fundamental research into "hardware;" the development phase of the project frequently occupies a substantial portion of the project time; and, the man-power "mix" is likely to include an unusually large number of scientists and engineers.

the advanced technology project manager . . . what must he do?

In learning to manage a group of professional employes, the usual corporate boss-subordinate relationship must be modified. The "how"—the details or methods of work performance by a professional employe—should be established *by the employe*. He must be given the facts necessary to permit him to develop a rational understanding of the *why* of tasks assigned to him. Moreover, if this employe is to be treated as a professional, high performance standards must be established for him, and he must be accountable for productivity at the professional level. In turn, he may be granted the prerogatives of a professional—freedom from detailed supervision, freedom from administrative routine where feasible, and working quarters that afford privacy and comfort. At the same time he must never be excused from the responsibility of having to *produce* in accordance with the exacting requirements of his profession.

A second unique aspect of the project manager's job is that his task is finite in duration. Unlike most managers, he is not privileged to see a reasonably long line of repetitive or similar functions stretching ahead of him. Nor can he modify his assembly line to manufacture a new product. He is managing a specific group of advanced specialists; the professional "mix" of his group is tailored specifically for the accomplishment of a mission.

If the project manager and his group are successful performers, they will complete all facets of their job—and thereby work themselves out of a job—in the shortest reasonable time. This may be a year or less, or five years and upward for long-range, high-budget projects. In any case, the project manager must trust his corporate management, implicitly in most cases, to provide him and his forces with continuity of work.

Another unique feature of the project manager's job is the absence of "feedback" information during the early stages, and often other stages, of his project. Under the servomechanism analogy of management control, a manager establishes a closed loop in which the performance output of his group is fed back to him, and compared with performance standards; corrective control action is then directed into the system.

The manpower "mix" for an advanced-technology project is likely to contain an unusually high proportion of scientists and engineers . . .

However, in advanced-technology work, during the design phase of a project and before test results of newly developed equipment are available, the project manager often finds himself like a pilot flying blind assisted by a relatively unproven set of instruments. His experience, judgment, and faith must carry him through until early test results become available, and from this first "feedback" he can modify the design approach in a direction most likely to meet the acid requirements of further proof tests. Meanwhile, during these periods of blind flying, he may be forced to make decisions that commit substantial funds or involve long-term commitments.

Essential to the project management concept is a clear delineation of authority and responsibility. The manager knows that his basic responsibilities are to deliver his end product (1) in accordance with performance requirements, (2) within the limitations of the budget provided him, and (3) within the time schedule specified by his customer. In general, the manager delegates by tasks, so that subordinate managers within his group have these same three responsibilities for subprojects. Success or failure may well hinge upon the manager's ability to discern fine variations in emphasis and resolve the continuous apparent conflicts among these three basic responsibilities.

During the life of an average project the relative importance of each responsibility may change several times. Woe unto the project manager whose interpretative apparatus is out of tune, or who for any reason fails to stay in phase with the governing one of the three basic responsibilities. Overemphasis on schedule may be fatal when dollars have become the governing requirement, or vice versa. Likewise, performance requirements must be met or trimmed to fit reality. The skillful project manager aims for a balanced emphasis upon the three responsibilities and maintains a position of sufficient flexibility that he can shift emphasis to meet circumstances.

Like the line manager, the project manager is at once a man of action, a man of thought, and a front man. As a man of action, his most important function is to establish and preserve a sense of momentum throughout all layers of his project. He must strive to avoid "dead center" situations in which general inertia seems to become overpowering and his technical people for the moment see no direction to advance. Thus, the usual

In the early stages of a project, the manager often feels like a pilot flying blind with an unproven set of instruments and controls . . .

management function of trouble shooting, or of unraveling the knots, occupies much of his time.

The first-line supervisors—the "supervising engineers"—are by definition the men who play the key roles in guiding the day-by-day progress of a project toward its goals. Such a supervisor often bears the same range of burdens borne by his manufacturing counterpart; demands upon his time can easily be overpowering if the project manager does not shield him from diversionary requirements. An illuminating experience for a project manager is to portray on a chart the number of line, staff, and customer offices that a supervisor must deal with in accomplishing his tasks.

However, a major danger lies within this supervisory situation. In attempting to shield a supervisor, to free him to concentrate chiefly upon the vital engineering job at hand, the project manager can unknowingly deal a severe blow to the supervisor's advancement potential. The manager must realize that the supervisor is at a critical point in his career, at which leadership capability and administrative potential can blossom or can be blighted. A general and basic tenet of management—the training of individuals for leadership—must not be shelved merely because the pace of an advanced-technology project seems at times to be overpowering.

In pursuing his objective of maintaining momentum, the project manager must be constantly aware of the apparent disdain for time commitments by some theoretically inclined scientists and engineers. While this attitude is a rather deep study in itself, one factor that must be understood is the drive for perfection in this kind of professional. Any kind of promised delivery date inevitably involves a compromise with perfection, in that the product or study must be cut off, wrapped up, and delivered at that point, thereby leaving dangling the further improvements the theoretician has come to anticipate. If allowed to run rampant, this tendency can result in continuous postponements of output.

As a man of thought, the project manager must be an organizational planner and an advance planner (within the time scale of his project). The crux of effective performance of a project lies in the interrelationship between organizational structure and individuals.

Skill in the somewhat mystical art of organization planning pays off for the project manager. This involves the correct tailoring of organizational structure to available individuals, and vice versa.

The project manager must simultaneously be a man of action, a man of thought, and a front man . . .

Although the organizational structure of a project is important, if not vital, it will not make up for inadequate caliber of technologists within the organization. Conversely, poor organization structure can tie up the output of topnotch engineers and scientists.

In advanced technology, sound organizational planning requires recruiting adroitness to acquire scarce talent both from within and without the parent organization. It involves the ability to utilize some engineers and scientists who do not measure up to reasonable requirements for the project—the ability to shape a team that can play over its head when necessary. Organization planning in a project cannot be done without a thorough understanding of the personalities, characteristics, and attitudes of the technologists, both of academic bent and practical bent, and both as individuals and as members of their particular professional methodologies.

In the matter of advance planning, the paramount duty of a project manager is the avoidance of crises that manifest themselves during the design, manufacturing, and check-out stages. Perfection will never be attained, and the best efforts of the manager can only reduce, but never eliminate, these crises. While the technological crises has become accepted as an inherent part of advanced-technology projects, each of these crucial periods leaves residual effects. First, the resolution of the crisis generally involves a sacrifice of engineering principle for expediency, which may in turn lead to subsequent crises. Second, each crisis, with its resultant need for immediate solution,

A project must be cut off, wrapped up, and delivered on time, and some improvements the theoretician had anticipated must be left dangling.

erodes the constructive attitude of the project's engineers and scientists, particularly the theoreticians. Therefore, the project manager must avoid crises wherever possible, and when they come he must fend off the ill effects as best he can. Unfortunately, *most* crises during the course of a project can be traced to lack of adequate advance planning.

At any time during the course of the project, the manager may be called upon to act as front man to help shape or reshape the policies that affect his project relative to the corporate structure and objectives. Contrary to uninformed opinion about the advanced-technology industries, "selling" is a never-ending job of a project manager. In acquiring scarce people, or scarce materials, the project manager must always be able to make an effective presentation, often on short notice. Many project managers have suddenly found themselves, in mid-course, fighting for the very existence of their project. While the outcome of many of these struggles is often beyond the influence of any actions taken by the manager, in other cases his actions as a fully informed representative of the project have a profound influence on the eventual outcome.

the project manager . . . what must he be?

In discharging his three basic responsibilities—to deliver a product that works, within budget, and on schedule—the project manager must be oriented to corporate management. He must not fail in these responsibilities or he cannot survive. He must understand corporate management; he must be at home in the economic dimension in which business operates, and he must understand the evolution of corporate policy and the nuances of its interpretation. His temperament and personality should be of a nature likely to gain respect in the front office for the project's problems.

Also vital to continuing success in project management is the manager's skill at providing an environment in which the productivity of the scientists and engineers is nurtured and maintained. If the project manager is to provide this critical environment, he must understand the role of the professional as an employe in industry, and the professional's reactions to modern corporate organization. These reactions have posed many broad problems, and if the manager is to be well informed he should be a student of current investigations on the topic. The handling of the problems of professional personnel may be the deciding factor in the success or failure of many companies in advanced-technology industry.

One of the honored cliches of the business world has been paraphrased in our new industries: "The only thing wrong with advanced-technology industry is advanced-technology people." These words are descriptive, but misleading. For in the new industries the people, more than ever, *are* the business. A company's material resources are of secondary importance compared to the caliber of its professional managerial and technological staff.

To establish a productive environment, the manager must be oriented to technology and to his technological employes. Otherwise his project will not prosper and he will eventually fail. A project manager is the man in between—the man who must possess a working understanding of two camps. He must serve as the mechanism for accomplishing the aims of his corporate management, at the same time serving as a perpetual buffer, so that engineers and scientists can meet the technological objectives that only they can define and only their output can meet.

"Projectitis" is a common difficulty; this is seeing all things as though a particular project were the center of the corporate universe—the alpha and the omega of the development effort. The project manager needs a modicum of projectitis to generate the necessary drive and momentum to spark the project to success. These symptoms of projectitis will be observed by his corporate management, but they will expect this malady and will themselves suffer with acute outbreaks from time to time.

A common misconception is that "the only thing wrong with advanced-technology industry is advanced-technology people."

However, when dealing with his engineers and scientists, the project manager must not suffer, or appear to suffer, from any blind case of projectitis in establishing schedular aims and policy objectives. If he does succumb to this tendency with his own people, perhaps as a result of pressure from an afflicted management, at least two adverse results may occur: (1) the technological advancement in the development of his product, which is actually the most basic of the project's responsibilities, will suffer; and (2) the human resources of the project—the most basic and important resources in advanced-technology industry—will be reduced in efficiency and show symptoms of the discontent that affects productivity.

The subject of communications deserves much attention in project management. The theoretically inclined technologist, generally a man of imaginative creativity, and often his engineering brother with a more factual creativity, regard the right to communicate as the bread of life for an adequate scientific career. Related to this principle is the cherished right to publish scientific work for the judgment of one's scientific peers.

Yet a contradictory element appears in the scientists' attitude toward communication. Observation of any professional technological group will show that some pay only lip service to the ideal of free communication, and in reality are more than hesitant in communicating the results of their work, or their attitudes or feelings on any topic, to anyone connected with administration. Dr. Vannevar Bush in his book *Modern Arms and Free Men* noted the distinctly different reactions to communications that he observed among military men on one hand and among academicians on the other. In the military, vigorous and open debate on proposed actions took place before the decision. But when an office with clearly constituted authority made the decision, the antagonists, acting under a basic doctrine of their profession, swung around to support actively the idea they had opposed. In contrast, under the customs prevailing in academic circles, the duly established decision signals the start of the fight. In this environment, it is difficult to learn the nature of the opposition to administrative planning, since academicians are not inclined to communicate freely in such matters. Consequently, after decisions are drawn there tends to be considerable passive and sometimes active resistance in the execution of these decisions.

The lessons here for the project manager are plain. He must expend considerable effort in learning to communicate adequately with his scientists, and in developing the communicative attitudes of his engineers. Scientists and engineers who work in the operating environment, and who practice advanced-technology development, *can* adapt their output to mesh with corporate schedules and corporate budgets, if they are *adequately informed* regarding corporate policies and objectives. Budgets and schedules must not be mere edicts, but should be carefully prepared within the cognizance of and with the aid of the technologists who must live by them. Occasional arbitrary actions originating in the realms of policy should be explained as carefully as possible, and on this basis will be accepted and implemented.

The temporal aspect of a project manager's task may strain his capacities in the art of human relations. Because the duration of a project is well defined, scientists and engineers will anticipate their next assignment, even though it may be a year or more away. This tendency can result in a kind of divided allegiance, in which the engineers look to others outside the project who may be able to help them in gaining their next assignment.

The project manager must counter this tendency to cast about for the next task, or it will diminish his effective control of the present task. The manager must be bulwarked by a potent company sales policy, which has provided and will continue to provide new projects for professional employes. When he has this backing, the manager need only follow a basic rule of managerial conduct—that of letting his people know where they stand. Frankness and integrity in discussing the future will allay their instinctive concern about the job that is over the horizon, and convince them that their role in future projects is assured unless they have been told otherwise.

aptitudes of a project manager

In examining these qualifications that a successful project manager must possess, the prerequisite training needs become apparent. The qualifications can be generalized as follows:

1. The project manager must be bred in the advanced-technology environment, so that he understands the pace, the people, and the relationships among contractors, subcontractors, and clients.

2. He should have a working knowledge of many fields of science, which he can augment when necessary to delve into the intricacies of a specific technology. He should have an inquiring nature and keep up to date in the many developments taking place in all advanced-technology fields. In regard to his knowledge, he should understand the fallacy of the oft-repeated concept that goes something like this: Scientists and engineers can respect only persons who are better scientists and engineers in their particular technologies, and by implication therefore, scientists and engineers cannot respect administrators, even those of technical grounding. If this were true, anarchy would exist in advanced-technology industries, because it is becoming increasingly impossible for one man to master sufficient technologies to obtain general respect under this theory.

3. He must have a good understanding of industrial administration and sales, and have the qualifications of temperament and character that qualify a man

When the end of their project is in sight, scientists and engineers begin to anticipate their next assignment . . .

The project manager must be bred in an advanced-technology environment . . .

generally for industrial management. He must understand the effects of policy as evolved in large organizations, since he will be working with industrial and governmental groups of large size and of considerable power. Importantly, he must have an understanding of *profitability* in the new and sometimes strange aspects it has assumed since World War II in the advanced-technology industries. This involves a thorough knowledge of the contractual mechanisms used to accomplish advanced-technology work—the fixed-price contracts, cost-plus contracts, and surely the "cost-minus" type of contract often referred to with acrimonious humor.

4. He must have the requisite faith and stability to carry him through the periods of blind flying when there is no feedback indicating the performance of his group nor of the products they are developing.

5. He must know the functions of each corporate staff specialty, and its relationship to his project. Generally he must alleviate the pronounced lack of understanding that his technological personnel will exhibit toward these staff groups. For example, purchasing is an important staff function affecting most projects. In buying many specialized components the typical project runs into a variety of purchasing problems, and their resolution can make or break the project's budget and its schedule. The project manager must also develop good two-way communications with corporate budget and fiscal planning groups, so that the project needs can be factored into corporate financial planning and so that the project can always be aware of current budget status. He must be able to talk the language of the comptrollership.

During the course of its lifetime, a project will be involved with corporate legal staffs and will find that a marked dearth of precedent exists in fields like nucleonics and astronautics. There will also be periodic negotiations with the personnel department, with its traditional difficulties in operating effectively where professional people are concerned.

6. The project manager must always remember that training is one of his basic responsibilities. In advanced-technology work, with its emphasis upon schedule and work output, the teaching aspects of management can be unduly subordinated. Under the concept of training responsibility, the manager must continually consider the preparation of first-line technical supervisors for further advancement into administrative roles. Likewise, the supervisor must be bolstered in providing the opportunity for professional and administrative improvement to the engineers and scientists within his group.

the integrative and analytical mind

In reviewing these qualifications, observe the emphasis upon the *integrative* function in the operations of the project manager. The requirement for the joining of many parts into a systematic whole is ever present. Integrative minds coordinate the productivity of all the functions in industry, and from the integrative mind industry receives its true directional guidance.

The processes by which the integrative mind works are largely indefinable, much as the requisite qualities for managerial personnel are not subject to scientific definition. Certainly the integrative mental processes must deal with intangible as well as tangible factors, and at times an intuitive process is needed in the formulation of judgment and decision. For instance, the highly complex reactions of human beings, at best only partially understood in our modern knowledge, must be thoroughly evaluated in most management decisions.

Conversely, a mind that is predominantly *analytical* wants to work only with facts that can be proven, and preferably in a specialized field of inquiry. The methodology of scientific analysis and experimentation has been carefully developed over many years, and is a part of the indoctrination of young men in training for a scientific career. This indoctrination breeds a distrust of intuition and a tendency to disregard intangibles. Further, the analytical mind will not draw its hypothesis until all relevant data has been observed and interpreted; any hypothesis drawn before this must be thoroughly qualified and hedged in the interests of scientific accuracy.

In project organizations, the analytical mind produces the concepts by which the project advances toward its goal. But without the integrative function, often nothing would be done with the concepts originating in the analytical function. A project manager must be capable of both integration and analysis, and must understand that the rigorous training of professional technologists with its emphasis upon analysis sometimes impairs their integrative ability.

the advanced-technology future

J. Sterling Livingston, Professor of Business Administration at the Harvard Business School, opened a recent essay with these significant words, "The most critical question facing the United States today is how it can regain undisputed technological leadership . . ." The character of American technological advancement during the next five years will shape our future and determine our survival or extinction.

The role to be played by project management in these years ahead will be challenging, exciting, and crucial. Truly it will be the acid test of the project manager and the project concept, but it will be more than that: It will be a momentous trial of free enterprise, business administration, and progressive industrial management as we know them today. ■

The project manager must have an integrative mind, the ability to join many parts into a systematic whole . . .

Texas-born Frank Rushing is living proof that characteristics attributed to Texans are more mythical than factual. Rushing's speech and actions are deliberate. His tastes are unembellished—he sports one of the oldest cars in the company garage, and his office has retained the same decor that it had ten years ago when he moved in as Manager of the Motor Engineering Department.

But in turn, his approach to the problems of management are also deliberate and unaffected by distracting details. Asked a question, Rushing usually leans back in his chair, turns the problem over in his mind, and says, "Let's see now . . .", then he runs down the possible solutions to see what the consequences might be. This is the key to his engineering and managing abilities—his thorough approach to a problem, and his desire to evaluate all possible solutions.

Rushing sets the pace for engineering work in his department by example of his own thinking, his dealings with people, and his insistence that his staff adhere to basic engineering principles. When asked how he attacks a problem, associates say that he sets out to find all the facts, and little is heard from him until he has seen the total picture in its correct perspective. Then and only then does he have suggestions.

These factors plus a patient, relaxed, but polished demeanor that puts people at ease, encourage his subordinates to give an undistorted view of a situation. Men working for Rushing say that this is extremely contagious. They, in turn, expect the same treatment from others.

Rushing graduated from the University of Texas with a BS in mechanical engineering in 1928. Even then his talent for engineering and management was becoming evident, as he was initiated into the scholastic fraternity, Tau Beta Pi, and was elected president of the senior class of engineering school.

After graduation, he joined Westinghouse on the Graduate Student Training Program. After some shop assignments and schooling on electric machine theory, the company sent him to Design School, and later to the University of Michigan for study in vibration and elasticity theory. To satisfy a heavy appetite for learning, Rushing supplemented this with night courses at the University of Pittsburgh, where he earned his MS degree in 1930. A few years later, he was initiated into the honorary scholastic fraternity, Sigma Xi.

Rushing then settled down in the Motor Department where he designed general purpose d-c motors and assisted with the development of a new line of heavy-duty steel-mill motors.

During the depression, Rushing's engineering talents were given the acid test. A much needed order (and in those days any order was much needed) was received for nine heavy-duty mill motors with the provision that they be shipped in nine days. If the order had requested a standard motor, there would have been no cause for concern; but this particular motor had never been built before, creating a design and manufacturing problem of mammoth proportions. To further complicate the situation, Rushing's boss, who usually handled such jobs, was away

Frank C. Rushing

and could not return in time to give assistance. Rushing was the only person even remotely familiar with the problem, so the job was placed in his hands. As soon as each phase of the design had been completed, manufacturing immediately began. Steel castings were transported, while still hot, to the machining sections. The first motor was shipped five days later, with the complete order being shipped within the nine days.

Rushing's engineering ability was formally recognized when he was awarded the Benjamin Garver Lamme graduate scholarship, given to young engineers or scientists who have demonstrated a capacity to do creative work of a high order. The Lamme scholarship provides the recipient with a year of advanced study at an institution of his own choice. Rushing attended the University of Charlottenberg, Germany, and studied electric machine design.

After completing his studies, Rushing capped his sojourn with a tour of Europe. He started from Berlin, passed through the Black Forest, down the Rhine to Cologne, up to Luxembourg, and then to Paris. From there he went to northern France, Belgium, and lastly, Holland. At first glance, this is a rather common excursion—but he traveled via bicycle some 1500 miles in eight weeks.

After his stay in Europe, Rushing returned to Westinghouse to work in the mechanics department of the research laboratories. Here he spent the most creative years of his engineering career, as evidenced by his award of the Westinghouse Order of Merit, the company's highest honor, ". . . for analysis, invention, and design in the field of dynamics."

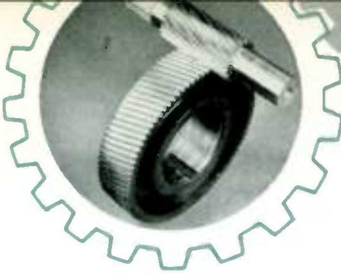
He first worked on the development of a rayon-spinner motor that could operate at 15 000 rpm with unbalanced loads; previously the limit was 6000 rpm. He then helped develop the Dynetric balancing machine that revolutionized balancing of rotating apparatus, from small motors up to turbine generators. The device uses a stroboscopic lamp and magnetic and electric circuits to detect vibrations as slight as one hundred thousandths of an inch, and indicate the amount and location of counterbalance.

At the start of World War II, switchboards, radar, searchlights, and other naval equipment needed shockproofing for battle service. The Bureau of Ships created an industry-wide joint committee to handle this work, and Rushing was appointed chairman. For his engineering services, Rushing was awarded the U.S. Navy Certificate of Commemoration.

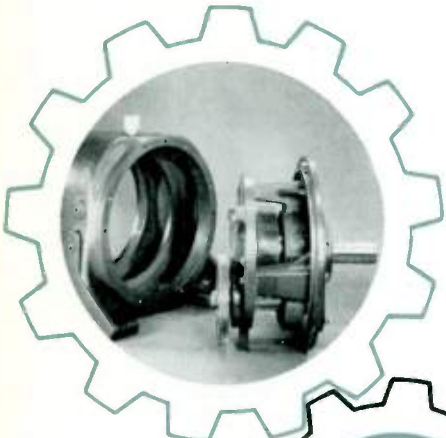
During the same period, calculations of Professor Urey indicated that U-235 and U-238 could be separated in a centrifuge. Rushing and a group of engineers went to work on the problem. Two years later, centrifuges had been developed and were performing successfully. Subsequently, the gaseous diffusion process proved more practical, but in recognition for his services, Rushing was awarded the Office of Scientific Research and Development Certificate of Appreciation.

In 1945, he returned to the Motor Division as Manager of A-C Motor Engineering. One year later he was made Manager of the Motor Engineering Department, his present position.

Though Rushing now is removed from actual design work, he sets the pace for good engineering in his department through his scientific but human approach to management problems. ■



A VERSATILE SYSTEM OF GEARS



A. S. DAVIS
Gearing Division
Westinghouse
Electric Corporation
Pittsburgh, Pa.

Fig. 1—(**Top**) The versatility of the Moduline system is largely due to the precision-ground gear teeth and the splined and threaded shafts. Close tolerances allow gears from one unit to be interchanged with another. (**Bottom**) The basic components used in all Moduline gear units are the gear housing, the low-speed cage, and the change gear (left end of low-speed cage).

A system of gear units, consisting of modular components, has been designed for versatility—but from this concept come many other advantages.

All motors and engines have optimum operating speeds. Likewise, the operating speed and torque of all loads are dictated by the application. Since the optimum speed and torque of the power source rarely equal the required speed and torque of the load, the two must be matched; this is frequently accomplished with a packaged gear unit.

Until recently, the application of gear units had been complicated by several factors. The extensive use of packaged units fostered development of many different designs, each with its own advantages and limitations, so that intelligent application required a working knowledge of many available types and their combinations.

Usually gear units outlast the machine on which they are applied. Unfortunately, however, the specially designed gear unit must often be relegated to the scrap heap when the machine is replaced. Also, a large inventory of replacement parts must be stocked for the wide variety of special units used in many plants, and these often become a total loss when a process or production line is changed.

In a new gear-unit system, a modular design is used, which not only alleviates these difficulties, but also provides greater reliability. With these new units, appropriately named the Moduline system, gearmotors, packaged drives, or speed reducers can be built from a basic group of subassemblies. From 15 modular subassemblies and seven Moduline frame sizes, at least 40 000 useful configurations can be assembled in the 1- to 40-hp range, which includes over three fourths of all gear applications (see pages 110 and 111).

the building blocks

The two basic subassemblies included in each Moduline drive are the low-speed cage, and the gear case. The low-speed cage (Fig. 1) is a cartridge-type structure which contains an output shaft, low-speed gear and pinion, and anti-friction bearings to carry internal and external loads. The gear ratio of the low-speed cage is 5-to-1. The gear case or housing is a sturdy, symmetrical, grey-iron casting with accurately machined open ends. The low-speed cage is attached to the housing with bolts. Many varieties of gearmotors, packaged-motor reducer drives, or speed reducers can be built from this basic unit.

The next components included in all units are the change gear and pinion. The total ratio of the gear unit can be varied in ten steps, from 0.83 to 5.0, with ten different change-gear sets. The change gear is mounted on an extension of the low-speed pinion of the low-speed cage. The change pinion is mounted on an extension of the input shaft or an intermediate shaft.

With the low-speed cage, housing, and change gears, a complete drive can be assembled by adding different subassemblies. A double-reduction reducer can be made by adding a reducer bracket and shaft assembly. Ratios from 4.17 to 25.0 are made from combinations of the variable-ratio change-gear set and the 5-to-1 ratio low-speed cage.

Gear ratios greater than 25-to-1 are made by adding a high-speed cage between the input bracket assembly and the housing; a high-speed cage contains a fixed gear set or sets. A triple-reduction cage uses one set of gears; two sets make a quadruple-reduction cage. The triple-reduction cage has a 5-to-1 ratio, and the quadruple-reduction cage, a 25-to-1 ratio. The total ratio of the unit is again determined by the ratio of the change-gear set. Triple-reduction reducers have ten standard ratios from 20.7 to 125, and the ratios of the quadruple-reduction reducers range from 103.7 to 625.

sizes

The smallest double-reduction reducer (Size 1) weighs 120 pounds and can be applied to drives from 10 hp, requiring a 4.17-to-1 ratio, to 1 hp at a 25.0-to-1 ratio. The largest quadruple-reduction reducer (Size 7) weighs 1640 pounds and is rated at 9 hp, with a 103.7-to-1 ratio, to 1.5 hp at a 625-to-1 ratio. In between are five other frame sizes with intermediate ratings. Ratings from 0.3 hp to over 100 hp can be obtained by changing the ratio of the basic unit.

mounting the gear units

Not all machines can be driven by floor-mounted or horizontal gear units. Many times the drive must be mounted on the side of a mixer, underneath a conveyor frame, or on top of an agitator tank. Such mountings are possible without basic changes in the Moduline reducer.

Each Moduline gear case has ten holes on the sides and top, which are used for filling, draining, and indicating lubricant level for different mounting positions. A breather, which permits air to enter or leave as the unit cools or warms, can also be installed in one of these holes. For normal horizontal mounting, the breather and oil-fill holes are located on the top of the housing, and drain and level holes on the side. Right-hand or left-hand side wall mountings and ceiling mountings also can be accommodated by moving the breather, drain, and level plugs to proper locations on the top and side of the unit.

A right-angle drive is required in many applications. Two types of right-angle heads can be used in such cases.

The low-speed output head fits against the low-speed cage and housing, and contains a set of spiral-bevel gears and bearings for internal and external load capacities. The head can be installed with its output shaft horizontal to the right, left, or vertical up or down. Intermediate positions in 30- or 45-degree steps also can be used, depending on the size of the unit. The output shaft is fitted with a face-type seal kit to prevent oil leakage when the right-angle head is installed below the horizontal axis of the gear housing.

The other right-angle head, the input head, is installed at the high-speed end of the unit in place of the concentric-shaft reducer bracket. It is much smaller than the output head because torque is less at this end of the gear train. Efficient spiral-bevel gears are used. The input head also can be indexed in 30- or 45-degree positions.

Gear units can be driven by almost any kind of power source or prime mover. Gasoline or diesel engines, steam turbines, pneumatic or hydraulic motors, waterwheels, and lineshafts are some of the less common types of drives. The electric motor, either a-c or d-c, is most often used, and the Moduline system includes a number of adaptations for it.

The drive motor and gear are usually mounted on a common bedplate, and connected with a flexible coupling. The bedplates are large enough to permit mounting of special motors and accessories, such as magnetic brakes, fluid couplings, and tachometer generators.

An integral gearmotor can be assembled by mounting a flanged motor directly on the gear box. Standard flanges and shafts are made for a-c and d-c motors. The pinion-forming part of the first gear reduction is mounted directly on the motor shaft, eliminating the need for a flexible coupling. Accurately machined fits between the motor flange and gear-box assure positive alignment at all times.

The motor can also be mounted on an overhung motor support or "sugar scoop." A flange on the reducer bracket supports the sugar scoop. The packaged-motor reducer drive combines the advantages of separate reducers and standard motors.

All drives can be equipped with the same gear ratios and frame sizes as the speed reducer. Wall, ceiling, or vertical mountings, and right-angle assemblies are also possible.

Single-reduction (5-to-1 ratio) and double-reduction (14-to-1 ratio) shaft-mounted speed reducer units are made by replacing the solid shaft in the low-speed cage with a hollow shaft. The cage is then enclosed in a lightweight cast-aluminum cover.

special adaptations

In many industries, reciprocating motion is needed to push materials from one table or conveyor to another, or from one work station to another. With a few additions, the basic Moduline unit can be converted into a motocylinder to provide the necessary reciprocating motion. The motocylinder is a self-contained gearmotor with a crank mounted on the output shaft.

A high torque motor and a set of integral cams and limit switches control motocylinder operation. The units can exert thrusts from 130 pounds to 50 000 pounds with stroke times of ½, ¾, or 1½ seconds. Repetitive stopping is assured within a few degrees, and the simple harmonic motion of the crank assures smooth movement of the linkages and load drives. A magnetically controlled brake or dynamic brake can be used to control operation.

Many machines cannot be allowed to reverse when not operating. Mechanical or magnetic brakes often are used to prevent reverse rotation, and they can be used with a Moduline unit. However, reverse rotation also can be prevented with a built-in backstop, which can be installed easily in the unit. The backstop is a positive sprag clutch that fits onto a shaft in the low-speed cage. It exerts no drag when the shaft is rotating in the forward direction, but a reversal of only a few degrees will engage it immediately.

In many industries, gear units must operate in severe environments. The shaft seal is most vulnerable to attack by corrosive liquids or atmospheres. Dual-seal kits can be installed to prevent entry of liquids or moisture as found in the paper, chemical, and other "wet" industries. They consist of a double-lip friction seal with a protective cover.

Abrasive dust or particles that exist in the cement, taconite, and similar processing industries can also be prevented from entering the gear unit. A mechanical seal kit is used consisting of dual-inner components, and an external flinger with a grease filled chamber.

manufacturing for modular construction

True modular construction requires absolute control of all manufacturing tolerances and processes. For example, the gear housing must be precisely machined if fits and alignments of all subassemblies are to be maintained.

The solution to this problem required the design and construction of the first automatic transfer machine in the gearing industry. The raw casting is bored, completely machined, and holes are threaded by a 21-station transfer machine.

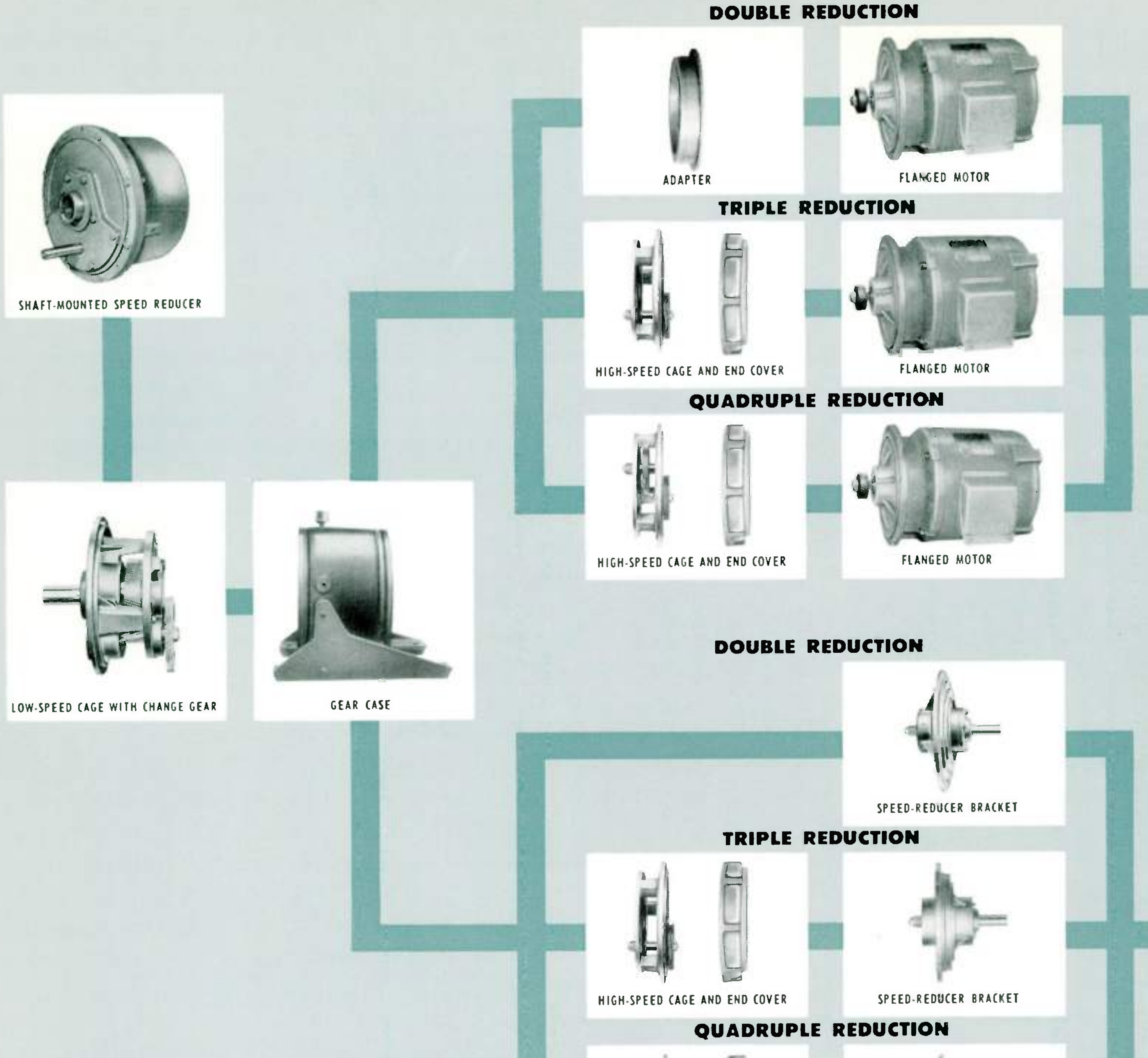
All demountable gears have splined bores, and the mounting shafts have splined serrations to hold the gear. An interference fit between the gear bore and the shaft is held to a minimum of 0.0002 inch and a maximum of 0.0007 inch. Thus a few taps with a lead or rawhide hammer can seat a new change gear if the ratio of the gear unit must be altered.

The gear bores are splined with a hydraulic broach. However, instead of machining the external spline on the gear shaft by conventional methods, the serrations are cold rolled into the shaft metal. No chips are made, and the cold working of the metal improves the finish and strength.

Each gear is ground to assure high accuracy. Prior to grinding, the gear or pinion teeth are rough cut and hardened by a spin-flame process to increase strength and resistance to wear. After tempering, the gear teeth are finish ground on a generating grinding machine, which produces a mirror-like finish and holds errors to low limits.

Gear and bearing losses are negligible because of ground teeth and anti-friction bearings. Every component is mated, and losses run from 1 to 1½ percent. Quiet operation is another benefit; the sound level of the Moduline gear unit is about 5 decibels below the conventional gear unit (for every 3 db reduction, the sound intensity decreases by 50 percent).

From many unrelated designs has come an unified group of gear units. A gear unit no longer becomes obsolete from a design standpoint—it need be replaced only when it is worn out (*see next page for flow chart of Moduline gear units*).



FLOW CHART OF MODULINE GEAR UNITS

The basic components in all Moduline gear units are the low-speed cage and the gear case. The cage and case can be used either in integral gearmotors or concentric shaft speed reducers with double, triple, or quadruple reductions. With slight modifications, the low-speed cage can also be used in the shaft-mounted speed reducer. Moduline units can be mounted vertically, horizontally, or at intermediate angles. Also, right-angle output shaft configurations can be made for special applications. Additional accessories are used to make motocylinders where linear reciprocating motion is required.

MOTOCYLINDER

INTEGRAL GEARMOTOR

RIGHT-ANGLE GEARMOTOR

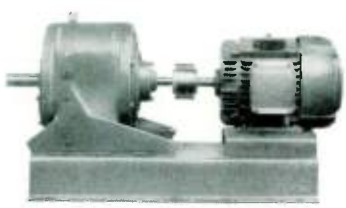
PACKAGED-MOTOR REDUCER

RIGHT-ANGLE PACKAGED MOTOR REDUCER

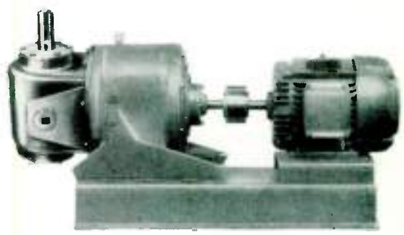
RIGHT-ANGLE OUTPUT SPEED REDUCER

CONCENTRIC SHAFT SPEED REDUCER

RIGHT-ANGLE INPUT SPEED REDUCER



BEDPLATE MOUNTING



BEDPLATE MOUNTING WITH RIGHT-ANGLE OUTPUT

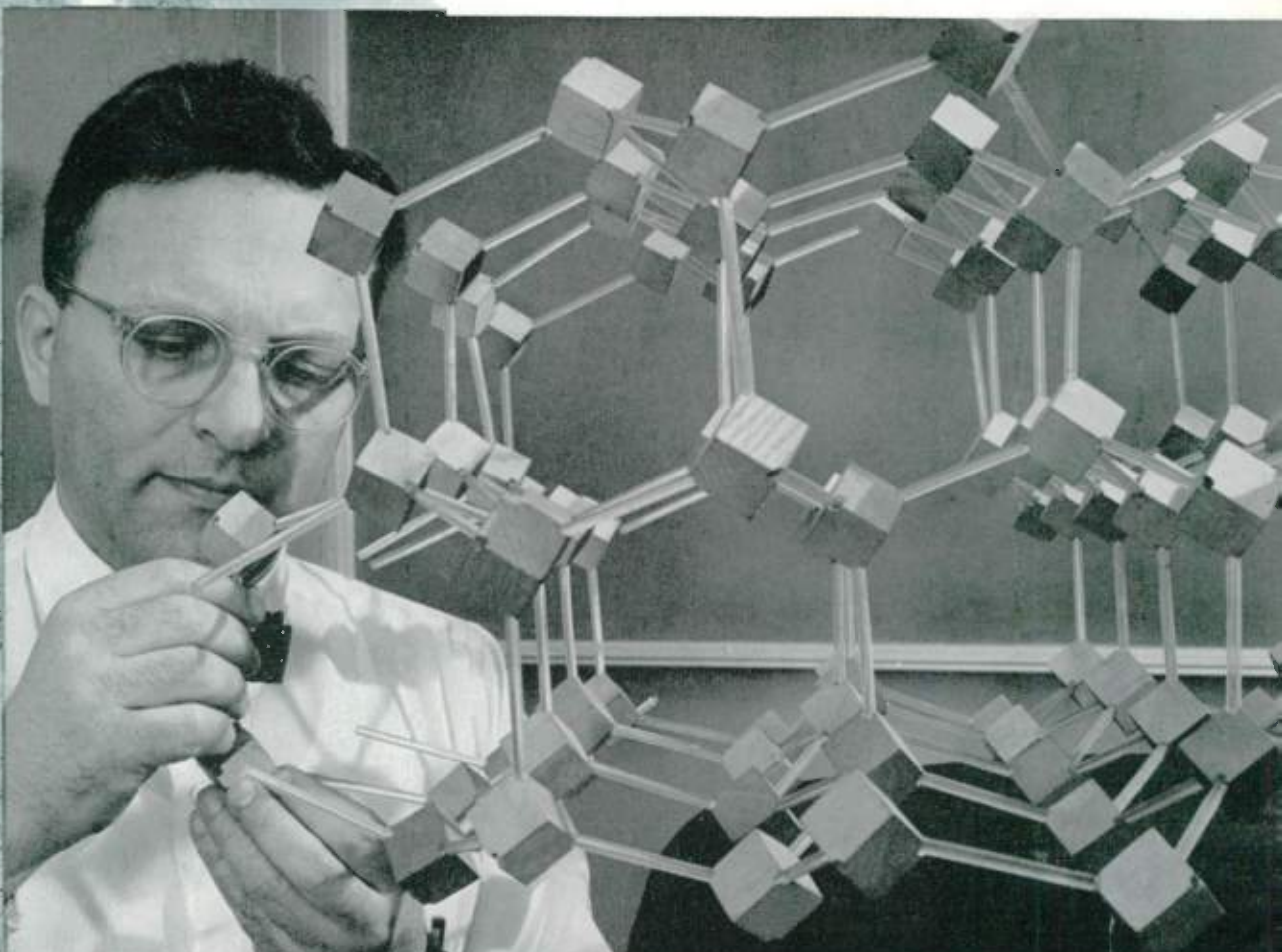
DENDRITIC GERMANIUM

. . . a step in the field of molecular engineering

New knowledge of materials has provided Westinghouse research scientists with the key to the discovery of a method for growing germanium crystals in a form ready for use. Called dendritic germanium (from *dendrite*, a tree-like crystal formed during solidification), these crystals are grown as thin, uniform flat ribbons, rather than the round ingot produced by present techniques.

The ease of processing dendritic germanium into usable form contrasts sharply with present practices. To process conventional germanium ingots into useful form, they must be sliced into thin wafers. Because germanium is hard and brittle, cutting is done with a diamond-tipped saw, and each slice must be three to five times the final thickness to prevent shattering. The slices are then ground to the required thickness, further cut into small squares, and polished. As a result of all this cutting and polishing, about 80 percent of the original ingot is lost as germanium "sawdust."

Not only is the dendritic germanium ribbon of the proper thickness, but its mirror-like surfaces need no grinding or polishing of any kind. As a result, the usual time-consuming and expensive processing of germanium into usable form is virtually eliminated. In fact, scientists envision a process that can continuously, automatically, and at reasonably high



This model of a new-type germanium crystal demonstrates how germanium atoms attach themselves in preferred locations to form a crystal in the form of thin, flat strips. The new method of crystal growth may eventually obsolete present techniques for manufacturing transistors and other semiconductor devices made from germanium.

speed, turn out finished transistors directly from an input of raw germanium and the two or three other materials required to put a transistor into final form.

Further research on the new development will be carried out under a $2 million development contract, issued to Westinghouse by ARDC's Wright Air Development Center as part of their broad program effort in the field of "molecular engineering."

The molecular engineering concept is a basically new approach to the building of electronic systems through the use of new knowledge of the structure of materials. It deals with dimensions comparable to molecules themselves, rather than merely an improved method of packaging components. Research results to date indicate that molecular engineering can lead to development of outer-space electronic equipment 1000 times smaller and lighter than anything now in existence.

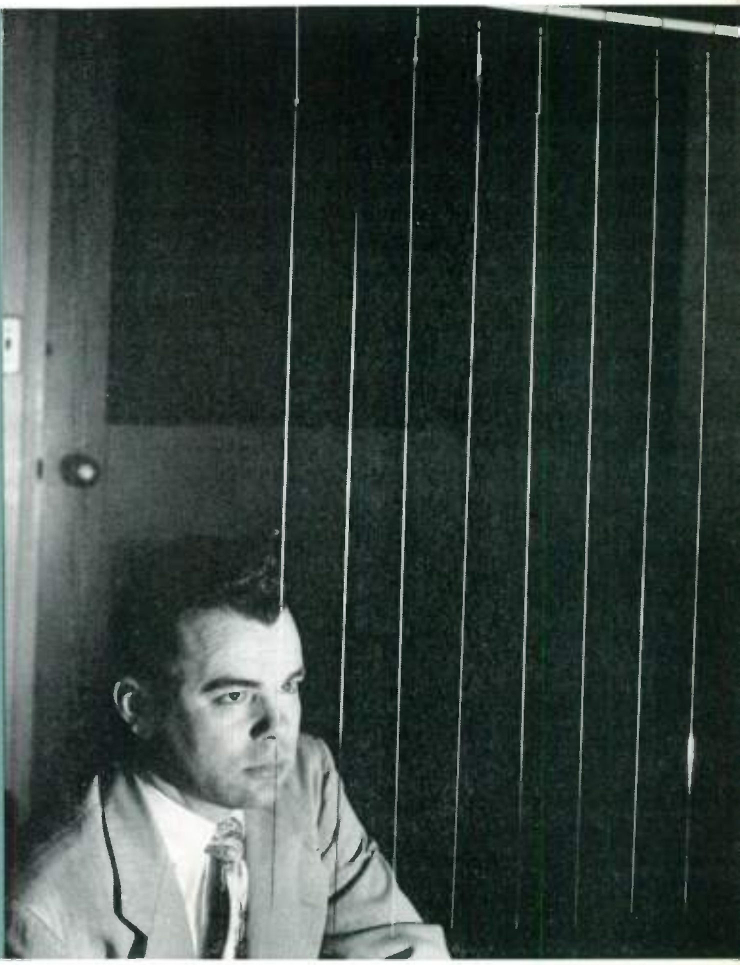
The ARDC has three major objectives under its molecular engineering development program: First, equipment designs with an inherent dependability, an inherent life that is long enough to do the job; second, a large reduction in the number of thermal energy consumers in electronic systems; and third, an increase by several orders of magnitude in the amount of electronic functions performed per unit of volume.

In applying molecular engineering concepts, very small pieces of crystal could perform functions that now require as many as a dozen present-day components using conventional circuitry. As an example of the size and weight reduction possible under the new concept, the Air Force has conducted demonstrations with a Westinghouse light telemetry subsystem that has a volume of only 0.001 cubic inch and a total weight of 0.02 gram. This equipment not only measures change in light intensity but also produces a signal capable of transmission to relate the degree of change in intensity. (This compares with the most modern system used to measure the intensity of light in space, which has a volume of about one cubic inch and a weight of approximately seven grams.)

Furthermore, the number of component parts in the telemetry subsystem was cut from 14 to 1 and the number of soldered connections was reduced from 15 to 2, thereby offering tremendous improvements in reliability.

Reliability takes on new meaning in the sophisticated applications destined to become commonplace in the future. When human life must be entrusted to the most complex electronic system ever developed, these systems must work the first time and continue to function perfectly for as long as required to perform the mission, regardless of environment. ■

A ribbon-like crystal of germanium rises out of a molten pool in this crystal-growing furnace at the Westinghouse research laboratories. Such thin, flat strips are the exact form in which germanium is used in making transistors and other semiconductor devices. Therefore, they require none of the costly, time-consuming cutting and grinding that wastes up to 80 percent of conventional ingots of germanium.



The long germanium "dendrites" grown by a new technique at the Westinghouse research laboratories have mirror-like surfaces. The technique, a radical departure from conventional methods, is the first major breakthrough in the preparation of germanium and other semiconductor materials since their commercial introduction some 10 years ago.

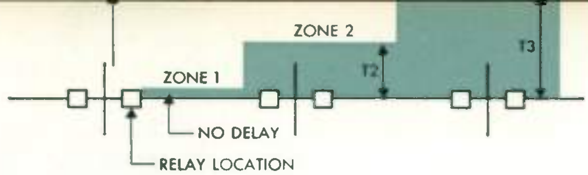


Fig. 1—Distance-time characteristic for three-zone distance-type relaying.

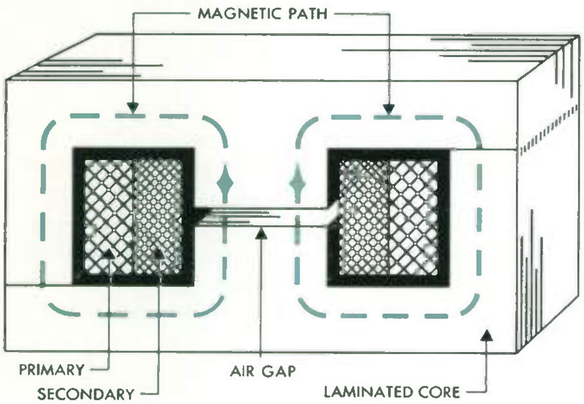


Fig. 2—Cutaway diagram of compensator construction, showing cross-section of winding.

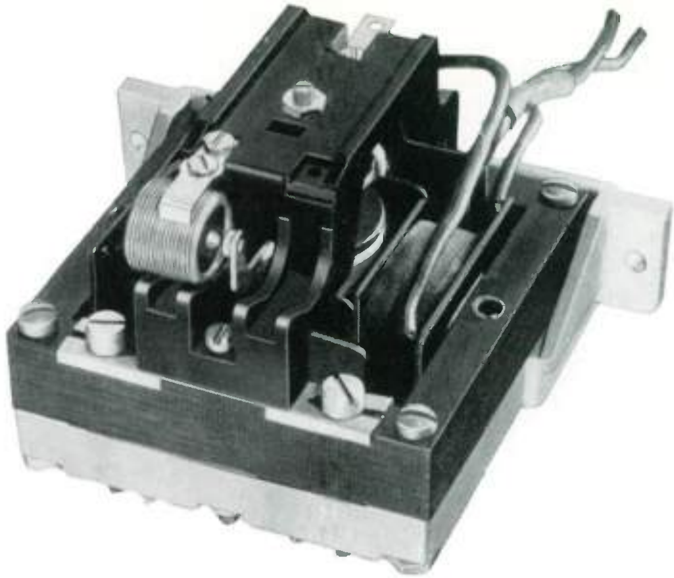


Fig. 3—This four-pole high-speed induction cylinder relay unit is used in K-Dar distance relays.

K-DAR COMPENSATOR RELAYING . . . a new concept in

This new approach to directional-distance relaying employs a polyphase concept to obtain greater reliability, simplified adjustment, and reduced maintenance.

H. W. LENSNER

Relay Engineering Department
Westinghouse Electric Corporation
Newark, New Jersey

Distance relays have been used for zoned phase-fault protection of transmission lines for over 25 years. Relay operation is dependent on abnormal voltage and current conditions that exist on the system during a fault. By comparing voltage and current at the relay location, the direction and distance of the fault from the relay can be determined. Depending upon the ratio of voltage to current (which is a measure of distance from the fault), the relay initiates breaker tripping with no delay, or after a fixed preselected time interval. The time-distance relationship for a three-zone relaying system is shown in Fig. 1.

The K-Dar compensator distance relaying scheme is a new and different approach to the problem of relaying interphase faults on transmission lines. In present conventional three-zone distance relaying systems, three single-phase relays are used for complete interphase fault protection, each relay consisting of three impedance measuring elements, one directional element, and one synchronous timer. In the new compensator scheme, a polyphase KD relay is assigned to a particular zone and not a particular phase.

Each relay case contains two separate polyphase relay units; one responds to all phase-to-phase faults in its zone, regardless of which pair of phases is faulted, and the second relay unit responds to three-phase faults. Thus, one or the other relay unit will respond to any fault within its protective zone, except single-phase-to-ground faults. This new high-speed, zoned-distance relaying scheme can be used with or without a power-line carrier or microwave channel.

K-Dar principle

Fundamentally, the compensator relay system is based on the operation of two basic components: a static compensator unit, and an induction-cylinder unit.

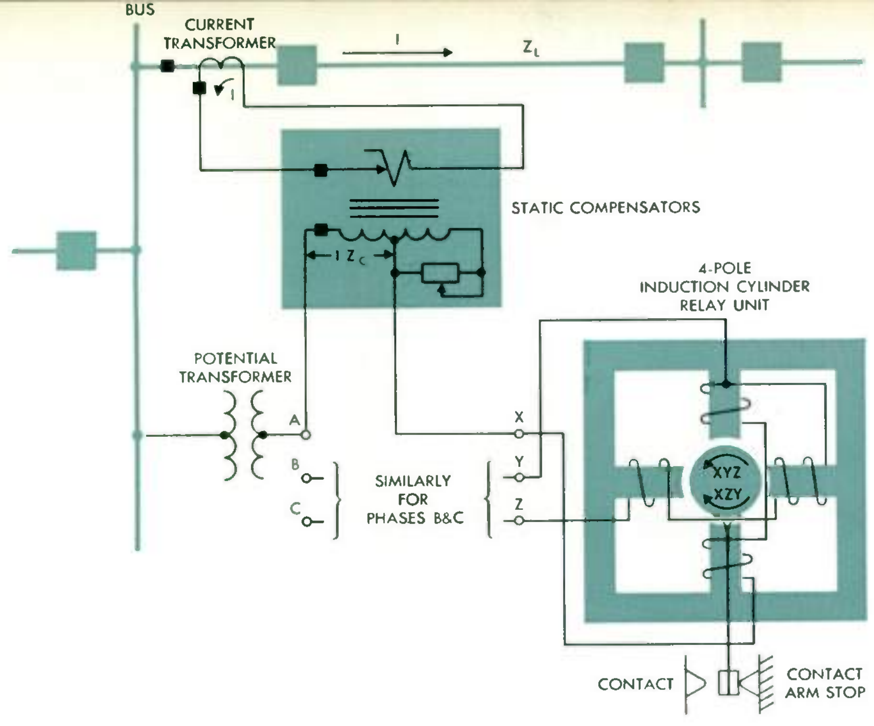


Fig. 4—Simplified schematic of K-Dar compensator distance relaying scheme.

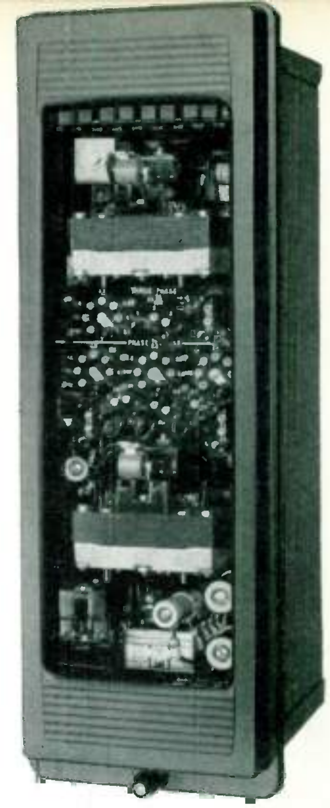


Fig. 5—Type KD compensator distance relay.

directional-distance relays

Static Compensator Unit—The key to the operation of the K-Dar relaying system lies in the *compensators*, from which the system receives its name. These static devices determine the "reach" of the distance relay.

The compensators are essentially air-gap transformers, with current-energized primary windings, and voltage-energized secondary windings. System voltage is applied to the input of the compensator secondary winding; a voltage proportional to the protected line impedance and to system current, which flows in the compensator primary winding, is subtracted from system voltage to give a difference voltage at the secondary output terminal of the compensator. Hence, compensator output voltage is affected by both system voltage and current, and by the impedance setting of the relay.

Compensator construction is shown in Fig. 2. The air gap is in the center of the core so that the outer portion of the magnetic path is entirely through laminations. With this design, compensator performance is relatively unaffected by nearby magnetic material; units can be mounted close together without magnetic interference.

Induction Cylinder Unit—A three-phase voltage, as modified by compensators, is applied to a high-speed induction cylinder unit, which develops either closing or opening torque depending upon the voltage applied.

The cylinder unit consists of an aluminum cylinder that rotates (enough to open or close its contact) in a magnetic field created by voltage coils on the four poles of the unit. The device functions basically as a polyphase induction motor. A particular input-voltage phase sequence causes the unit to rotate in one direction; if the phase sequence is reversed, the unit rotates in the opposite direction; and finally, if two phases are tied together and a single-phase voltage applied from the tie point to the remaining terminal, the unit will not start. Thus, the cylinder unit is in effect a decision-making device.

Two separate identical cylinder units are used in each KD relay, one in a phase-to-phase relay unit and the other in a three-phase relay unit. The difference is the number of static compensators used in each relay unit.

Phase-to-Phase Relaying—The a-c voltage and current circuits of the phase-to-phase relay unit of the compensator relay are shown schematically in Fig. 4. Three line-drop compensators are used, one in each phase, to produce potentials that in effect are system voltage modified by the line-current induced drop (IZ_c) through the compensators; these modified potentials are applied to the cylinder unit coils. The phase rotation of the three-phase voltage thus obtained is such that with no line current flowing, the relay produces a restraining torque and the relay contact is held open. The mutual impedance (Z_c) of the compensators is set equal to the desired line balance-point impedance in terms of secondary ohms. By means of a loading resistor connected across a portion of the secondary winding of each line-drop compensator, the angle between the primary current and the secondary voltage of the compensator can be made equal to the angle of the protected line section.

Three-Phase Relaying—Because of the symmetry of the phase-to-phase relay connection shown in Fig. 4, this configuration will not respond to a balanced three-phase fault. Therefore, the three-phase portion of the compensator relay is connected basically as shown in Fig. 4, but only a single compensator is used. It is connected in one phase of the circuit. The compensator must have a mutual impedance equal to 1.5 times the desired balance-point ohms. The other voltage terminals of the cylinder unit are connected directly to the line potential transformers.

operation during faults

For both relay units, under normal conditions without a fault on the system and with a given phase sequence, the cylinder unit develops torque in the contact-opening direction. When a fault occurs beyond the balance-point setting of the relay, the voltages applied to the cylinder units remain of normal phase sequence, and the cylinder unit maintains open contacts. If the fault exists at the balance point, the voltages applied to the cylinder units are reduced to a single-

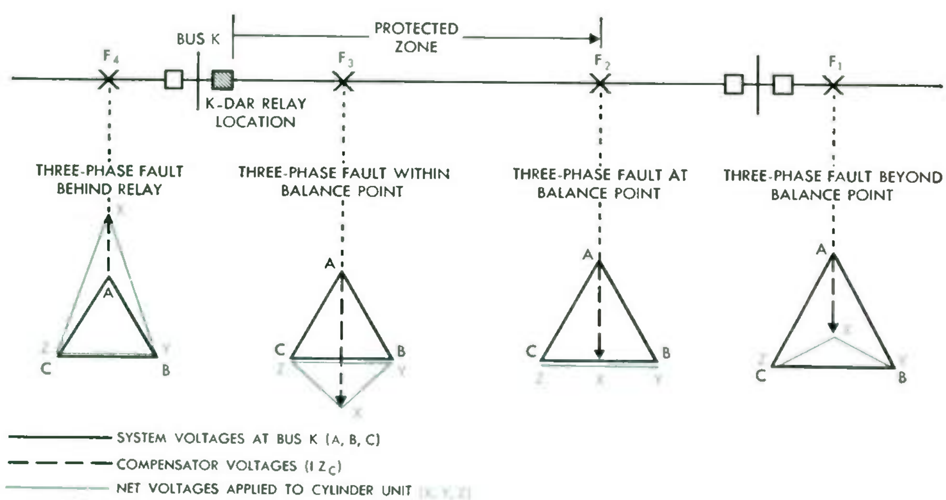
OPERATION OF THE PHASE-TO-PHASE RELAY UNIT

These voltage diagrams illustrate the phase-to-phase portion of the compensator distance relay operation for a phase B-to-C fault at various locations on the transmission system. The relay under consideration is located at the shaded breaker. For simplicity, the relay angle is assumed to be equal to the angle of the protected line-section. For a BC fault *beyond* the relay balance point, the system voltage triangle at bus K has collapsed only slightly, as shown at location F_1 (triangle ABC). With fault current flowing in phases B and C, the voltages (IZ drops shown dotted) developed by the associated compensators are subtracted from the system voltages to yield a modified set of voltages XYZ applied to cylinder unit terminals. Since no fault current flows in phase A, the potentials of point A and point X are the same. The triangle of voltage (XYZ) applied to the cylinder unit has a phase rotation X, Y, Z, which produces contact-opening torque.

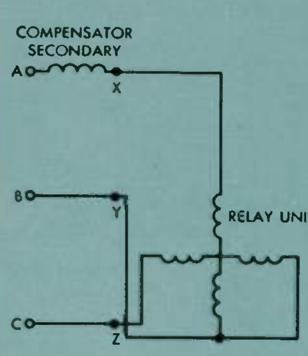
If a BC fault occurs *at* the relay balance-point (location F_2), the compensator voltages BY and CZ add up to exactly the value of the collapsed BC voltage, so points Y and Z coincide. Thus the XYZ triangle is reduced to a straight line and there is no phase rotation. Under this condition, the cylinder unit has no tendency to rotate in either direction. This is a balance-point condition for the phase-to-phase relay unit.

For a fault *within* the zone of operation of the relay (location F_3), the BC voltage is further collapsed. Now the sum of the compensator voltages in phases B and C is greater than system voltage, and the positions of points Y and Z actually cross. (For clarity, the BY and CZ compensator voltages are slightly offset.) The resulting voltage triangle now has the phase rotation XZY, which produces contact-closing torque on the cylinder unit to trip the breaker. As the fault gets closer to the relay location, the BC voltage approaches zero, and the XZY triangle increases in area, giving more closing torque.

Finally, for a BC fault *behind* the relay (location F_4), the direction of fault current through the relay has reversed, which reverses the polarities of the compensator voltages, BY and CZ. As before, the potentials of points A and X are the same. The resulting voltage applied to the cylinder unit this time has phase rotation XYZ, which again produces contact-opening torque. The performance for other phase-to-phase faults is similar. Thus, this portion of the relay operates for any phase-to-phase fault between the relay location and the desired balance point, but will not operate for any fault outside this zone.



FOR SIMPLICITY, THE FAULT CURRENTS AND PHASE-TO-NEUTRAL VOLTAGES ARE NOT SHOWN.



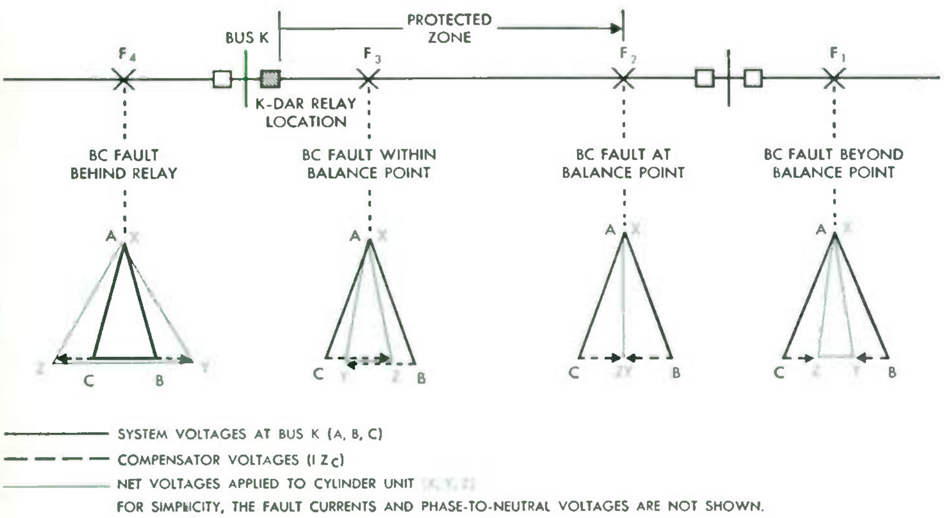
THREE-PHASE UNIT

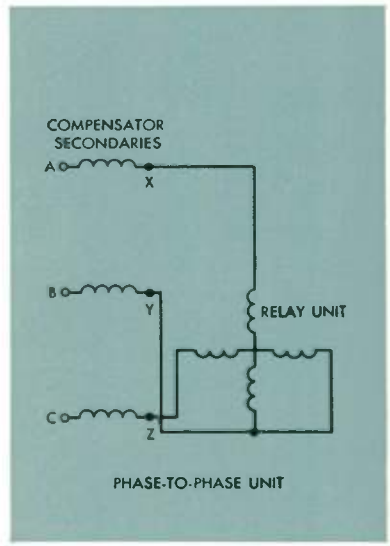
phase condition, and no torque is developed in either direction. A fault on the transmission line within the protected zone between relay and balance point causes a phase reversal of the voltages presented to the appropriate cylinder unit (depending on the type of fault), and the relay contacts close. If a fault occurs behind the relay location, the voltage phase sequence applied to the cylinder unit remains normal and the relay contacts do remain open. The actual voltage conditions for phase-to-phase and three-phase relay operations are shown below.

relay characteristics

One of the most important characteristics of a distance relay is its ability to trip at the same value of impedance (distance) over a wide range of system current and voltage conditions. This characteristic is usually shown by a plot of impedance (or percent of relay setting) at which the relay trips, as a function of relay voltage. The designer strives to make this curve as flat as possible. The performance of the compensator distance relay, shown in Fig. 7, indicates that over a broad voltage range, the relay has an essentially constant reach. This means that over a wide range of fault conditions, the relay will cover the same portion of the protected line section. In addition, because of the inherent design of the relay, it will not overreach on d-c transients, which accompany faults on high-angle lines.

Another important characteristic of a high-speed relay is its operating time. Time curves for both phase-to-phase and





OPERATION OF THREE-PHASE RELAY UNIT

This series of voltage diagrams illustrates operation of the three-phase portion of the compensator relay. The relay being considered is located at the shaded breaker, and the relay angle is assumed to be equal to the angle of the protected line section. For a three-phase fault *beyond* the relay balance point, the system voltage ABC at bus K is as shown under location F_1. Although fault current is flowing in all three phases, only the phase A voltage is modified, since the three-phase portion of the relay uses only a single compensator connected in the phase A circuit. The phase B and phase C voltages are unmodified, thus points Y and Z will always coincide with B and C, respectively. For this fault, the compensator voltage will locate the potential of point X above the BC voltage line as shown. Thus the cylinder unit voltage (in color) has phase rotation XYZ, which produces contact-opening torque and the relay contact is held open.

For a three-phase fault *at* the relay balance point (location F_2), the compensator drop AX is just sufficient to put point X on the BC voltage line. The XYZ triangle collapses to a straight line with no phase rotation, and the cylinder unit has no tendency to rotate in either direction. This is the balance-point condition for the three-phase unit.

For a fault *within* the protected zone (location F_3), the ABC voltage triangle has further collapsed. This time the compensator voltage AX crosses the line of the BC voltage, and the voltage applied to the cylinder unit has XZY rotation, which gives contact-closing torque to the relay unit. For an internal three-phase fault very near the relay location, the ABC triangle approaches zero in size. To handle such a condition, a tuned circuit in the relay maintains the BC voltage long enough for the relay to trip.

For a three-phase fault *behind* the relay (location F_4), the direction of fault current through the relay reverses, which in turn reverses the polarity of the compensator voltage AX. The resulting voltage applied to the cylinder unit for this condition again has XYZ phase rotation, and the relay contact is held open. This portion of the compensator relay operates for a three-phase fault between the relay location and the desired balance-point, but not outside these limits.

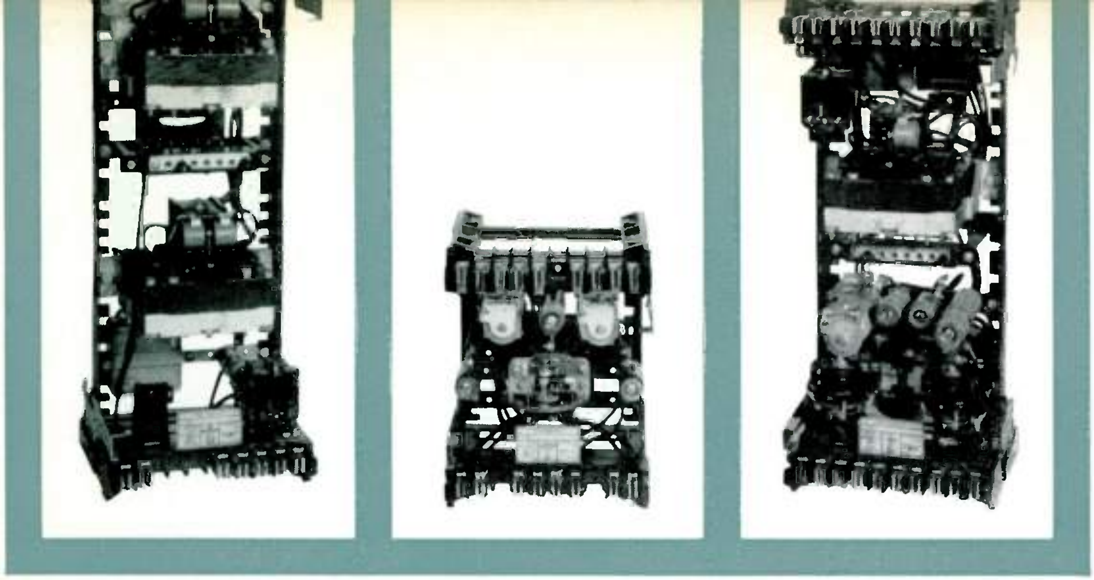


Fig. 6—Other K-Dar relays in carrier control system: **Left**—Directional overcurrent ground relay (Type KRP): **Center**—Time-delay relay for zones 2 and 3 (Type TD-2); **Right**—Carrier auxiliary relay (Type KA).

three-phase relays are shown in Fig. 8. For close-in faults, the operating time is as low as 10 milliseconds (about $\frac{1}{2}$ cycle on a 60-cycle basis). For faults farther away, but within the relay setting, the relay-operating torque is less, and operating time increases.

other K-Dar relays

The term K-Dar applies not only to the type KD compensator-distance relay, but also to a whole family of new protective relays used together to provide a complete directional-comparison carrier relaying system for application with power-line carrier, microwave, or pilot-wire channels. The entire family includes: the KD relay, used for zone 1 and zone 2; the KD-1 relay, a modified compensator relay for zone 3 and carrier-start use; the TD-2 timing relay, to produce the second- and third-zone time delays; the KRC, KRP, and KRD, directionally-controlled instantaneous overcurrent ground relays with current, potential, or dual polarization, respectively; the KA, a carrier auxiliary relay; and the KS, an out-of-step blocking relay. Three of these relays removed from their cases are shown in Fig. 6.

The induction-cylinder relay unit used in the KRP and KA relays is the same type as in the KD relay. By using a single relay-unit design for all a-c functions (distance, direction, and overcurrent), the time coordination problem at the initiation and clearing of a fault is greatly simplified.

summary

The K-Dar distance relays present a new approach to the relaying of transmission lines. The polyphase concept makes possible complete phase-fault coverage for each zone of protection with only two operating units. The use of fewer operating units provides greater reliability, simplified adjustment, and reduced maintenance. The static compensators can be manufactured to close tolerances in mutual impedance, which results in a relay capable of high accuracy in calibration and setting. Because of the insensitivity to system transients, the relays can be set to cover a greater portion of the protected line-section. The packaging of the relays by zones rather than by phases gives improved flexibility of application. Depending on the application requirements, the K-Dar relays are adaptable to straight distance-type protection or in combinations for directional-comparison carrier, microwave, or pilot-wire systems with greatly simplified circuitry. ■

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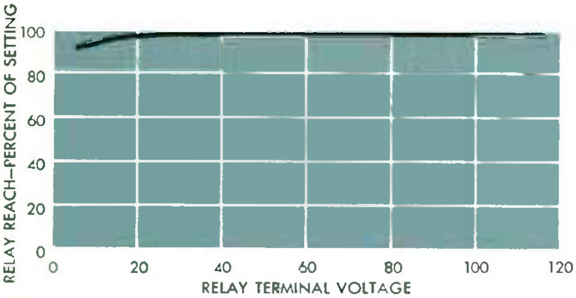


Fig. 7—(**Above**) Impedance characteristic curve of the KD relay.

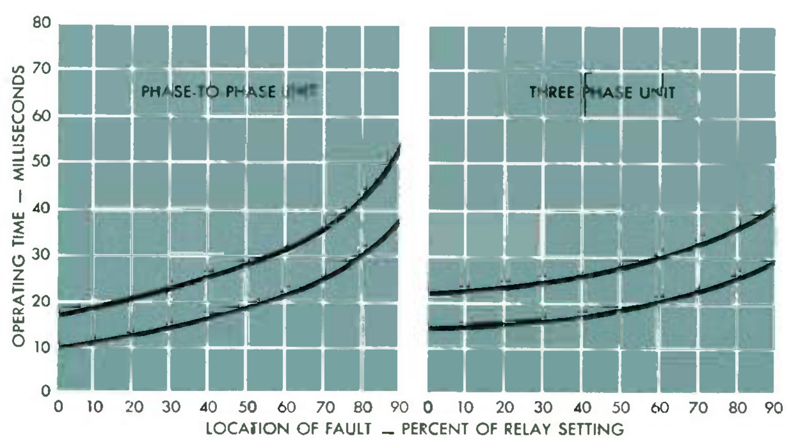


Fig. 8—(**Right**) Typical operating time curves for KD compensator distance relay.

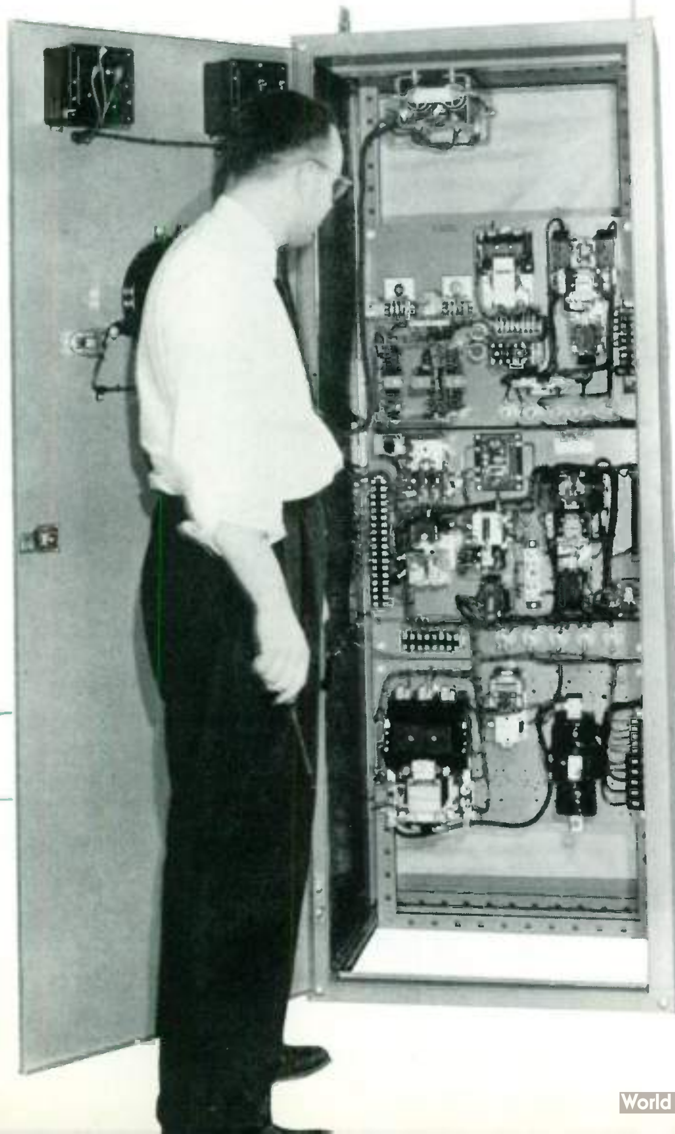
IMPROVEMENTS IN SYNCHRONOUS MOTOR CONTROL WITH TRANSISTOR LOGIC

The use of semiconductors has reduced the size, weight, and maintenance of the synchronous motor starter. In addition, electronic circuitry and fast switching devices make possible more accurate sensing of motor conditions.

DEAN J. MacGREGOR **RICHARD M. HAYFORD**
General Purpose Control Department
Westinghouse Electric Corporation
Buffalo, New York

Semiconductor materials have made possible a new concept in motor control. The transistor can now replace the conventional magnetic relay and be used as the basic building block of control systems. In a new static starter for synchronous motors, switching transistors perform complex logic operations, including: application of motor-field excitation at both the proper speed and the most favorable rotor and stator relationship; detection and removal of excitation if the motor pulls out of synchronism; and protection of the starter or damper winding from overheating when operating at subsynchronous speeds.

Transistors have the advantages of small size, reliability, low power requirements, rapid switching ability, and inherent amplifying characteristics. In addition, their use in motor control eliminates many of the variables of the present magnetic-relay type starter. The operation of the relay starter depends on such variables as spring tension, magnetic properties of the iron, air gap, etc. The transistorized starter, on the other hand, eliminates these variables with a resulting improvement in accuracy of operation.

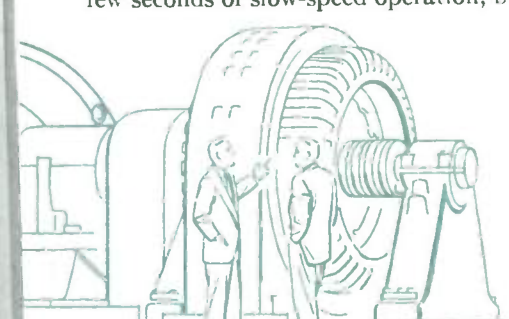


control for starting and running synchronous motor

Starting—A synchronous motor is started by connecting the stator to a three-phase supply at either full or reduced voltage. Simultaneously, the field winding is connected to a discharge resistor, both to protect it from damage by high induced voltages and to allow development of accelerating torque. In addition, high currents induced in a damper winding, embedded in the rotor, develop a major portion of the accelerating torque, particularly at low speeds. When these torques have accelerated the machine to a speed within one to five percent of synchronous speed, the field is connected to the excitation power supply, and the resulting torque pulls the rotor field into step with the rotating stator flux. Maximum synchronizing torque is produced if excitation is applied during the correct relative position of the rotor and stator flux. If switched at this point, a heavy load can be synchronized with minimum electrical and mechanical transients.

Pull-Out—If the torque required by the load exceeds the synchronous torque developed by the motor, the rotor will pull out of synchronism. Because the net torque of an excited motor after pull-out is too low to prevent rapid deceleration, very severe electrical and mechanical transients occur. If, however, the control can rapidly detect pull-out and remove the field excitation, the motor will run as an induction machine with greatly increased torque. Therefore, the control should also detect subsynchronous operation and either remove the excitation rapidly, or disconnect the motor.

Damper-Winding Protection—A synchronous motor control also should protect the damper winding from overheating. Because this winding is used only during starting, it is rated for intermittent operation and burns out sooner than the stator winding, which is rated for continuous operation. Damper-winding protection must shut off the motor after a few seconds of slow-speed operation, but must allow a longer



This static synchronous motor starter can be applied to any size machine simply by adjusting with potentiometers (1) the input voltage (clipping network), (2) the synchronizing speed setting, (3) allowable locked-rotor time, and (4) the operating curve for the damper-winding protection.

trip time as the speed increases if the full starting capabilities of the motor are to be used.

magnetic-relay type starter

Relays used in the present synchronous motor starter, called Slipsyn, have some limitations. Speed-measuring and angle-switching functions are performed by a d-c relay energized by a rectified signal proportional to the frequency of the induced field current. This frequency is directly proportional to motor slip; therefore, relay flux builds up during the forward half cycle and then decays during the blocked half cycle. When the duration of the blocked half cycle becomes sufficiently long (indicating the motor is running near synchronous speed), the flux decays to a value low enough that a spring on the synchronizing relay can operate the relay contacts and initiate closing of the field contactor. The time delay inherent in this relay also provides angle switching, if properly adjusted. Operation of this relay depends on numerous variables, such as the magnetic properties of the iron, the air gap in the magnetic circuit, the force characteristics of the opening spring, and the current in the coil. These variables make the relay difficult to adjust initially and the adjustment may change during operation.

Pull-out protection of the Slipsyn starter uses a transformer-relay combination, which must be sensitive enough to detect a pull-out signal. However, some transient electrical or overload conditions produce a similar signal and cause the control to react unnecessarily.

The damper-protection device uses the frequency-sensitive characteristic of a current transformer to supply a current that heats a bimetallic element. When the bimetallic element reaches a certain temperature, it disconnects the motor from the power supply. Because the characteristics of the transformer-bimetal combination are not directly related to the heating effects of the damper winding, the relay cannot accurately sense overheating under all conditions. This results in a loss of protection over half synchronous speed.

advantages of static synchronizer

The new Static Slipsyn starter overcomes these limitations by using transistorized logic elements to perform all the sensing and coordinating operations. Now the motor field can be applied accurately up to 99 percent of synchronous speed. Also, pull-out protection is now adjustable from 1 to 8 poles of slip, eliminating tripping due to transients.

Major functional components of the control are indicated by white boxes in Fig. 1. The field-excitation and the a-c circuits are similar to those of relay-type starters except that the control elements do not require a d-c supply; a small transformer energized from one phase of the a-c supply provides all the power required by the transistor circuits.

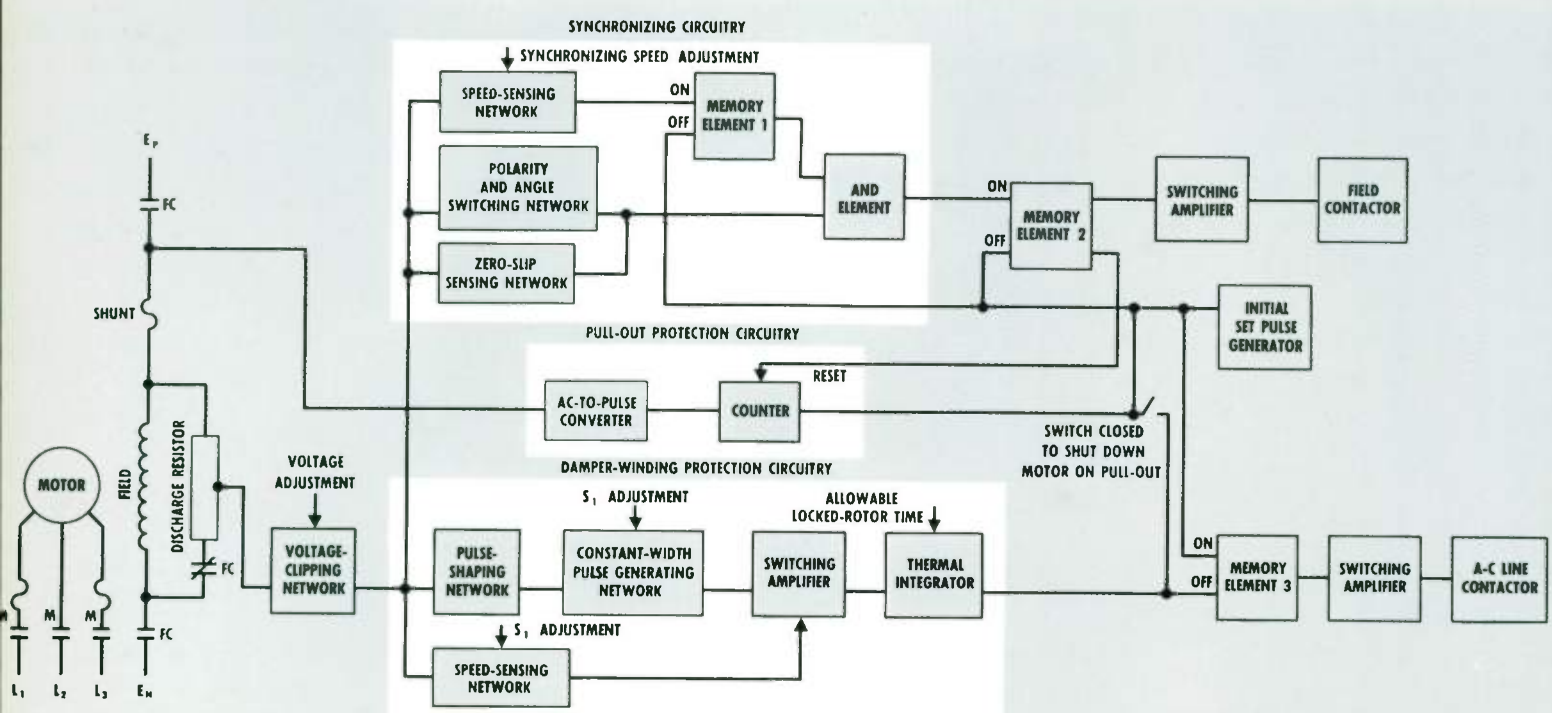
In addition to the usual advantages of static controls, this new Static Slipsyn starter has several other significant features. Use of small, lightweight components, as opposed to the large operating coils, magnetic structures, and conductors allows the circuits to be built on small, functional, insulating boards, Fig. 2. Due to the low-power requirements of the new starter, all power can be obtained from the a-c supply; several supply voltages can be obtained from a multitap primary on the supply transformer. Thus a single assembly can be used for most applications without component changes.

The starter is assembled with a wire-wrap technique that eliminates printed-circuit boards and dip soldering. Because the starter is grouped into functional modules, which are mounted on separate boards, detection and replacement of defective parts are simplified. For example, failure of the starter to detect pull-out indicates that the *pull-out module* is defective; only the pull-out module need be replaced. The only instrument required for trouble shooting is a voltmeter that can detect the presence or absence of a 20-volt signal.

operation of static synchronizer

An input signal, indicating the motor operating conditions, is developed across part of the field-discharge resistor. Its frequency is inversely proportional to the motor speed, and its instantaneous value indicates the relative position of the rotor and stator poles. The *voltage clipping network* limits the input signal so that fluctuations in magnitude do not affect the operation of the circuits. The output of this network is a constant-voltage signal whose frequency varies with motor speed. For initial adjustment, the input voltage is increased until a lamp indicates proper signal clipping.

Starting—To synchronize the motor, the input signal is applied to the *speed-sensing network* (Fig. 1), which provides an



output only when the motor speed reaches a preset value. This output turns on *MEMORY 1*, providing a continuous signal to the *AND* logic element indicating the motor has accelerated to synchronizing speed. The second input to the *AND* element comes from the *polarity and angle switching network*, which produces a narrow pulse each time the rotor pole reaches the position most favorable for synchronization. The *AND* element, therefore, produces a momentary output at the optimum time for application of the excitation. This output turns on *MEMORY 2* and its amplified output energizes the field contactor to apply the excitation, Fig. 3.

A motor starting with a light load can rapidly accelerate and synchronize by reluctance torque before the excitation is applied. If this happens, the field does not have to be applied at an optimum time, since the rotor position is already fixed with respect to the stator poles. The *zero-slip sensing network* detects synchronization by reluctance torque, and provides an output signal that takes the place of the polarity and angle switching network output. This signal plus the synchronizing speed signal provide both inputs to the *AND* element for application of the excitation.

Pull-Out—The pull-out protection circuitry makes up the second portion of the control. A signal developed across an instrument shunt in series with the motor field is applied to the *a-c to pulse converter*, which produces a series of narrow pulses that are stored in the *counter*. A preset number of pulses (usually two or three) cause an output that switches off *MEMORIES 1* and *2*, which, in turn, remove the excitation and reset the synchronizing circuitry in preparation for resynchronization when the overload has passed. The signal can turn off *MEMORY 3*, thus removing the motor from the line if, for instance, the overload must be manually corrected. Pulses remain in the counter for a short time so that a single stored pulse is forgotten after a few minutes. A reset signal prevents storage of any pulses during transients incident to synchronization, and also provides for instantaneous reset after pull-out is signaled.

The counter type of pull-out sensing can differentiate accurately between transient conditions, such as momentary mechanical overloads, supply voltage dip, etc., and true pull-out. A transient, which can produce conditions within the motor very similar to those at the beginning of pull-out, may cause an input to be registered at the counter; but by definition, a transient does not reoccur. Therefore, only true pull-out can cause a counter output.

Damper-Winding Protection—The *damper winding protection circuit* uses the same input signal as the *synchronizing circuit*, but in a different way. This circuit converts the slip frequency to a series of pulses, one for every half cycle of input signal, which trigger a circuit to form a pulse of constant width. Amplifying to a constant magnitude produces a pulse containing a fixed quantity of energy, since both magnitude and width are constant. These pulses are triggered at a rate proportional to the slip; therefore, the quantity of energy per unit time is proportional to the slip of the machine. This energy is integrated so that the sum represents the total energy absorbed by the damper winding and thus serves to simulate its temperature. When the sum reaches a preset magnitude, the circuit produces a signal that turns off *MEMORY 3*, opening the a-c line contactor.

An examination of the damper-winding current versus speed relationship, both from a theoretical and a practical standpoint, shows that for many motor designs, a damper-winding current of constant magnitude is induced from standstill to some slip, designated S_1. As the slip becomes less than S_1, the current decrease can be approximated closely by a simple mathematical relationship. The value of S_1, which can be determined easily from the machine design constants, matches the protection operating characteristics to the particular machine. The speed-sensing network in the damper-winding protection circuit provides a signal when the slip is greater than S_1. This signal maintains continuous output from the amplifier and thus simulates a constant rate of heating in the damper winding. After the slip reaches S_1, this output is cut off, and the constant-energy input to the integrator changes to a rate proportional to slip. The value of S_1 also adjusts the width of the pulse output of the *constant-width pulse generating network* so that the two characteristic curves will be continuous in the region of S_1, giving good protection at low slip, Fig. 4.

The advantages of electronic circuitry could never before be realized in industrial controls. Now semiconductor devices, and particularly the transistor, have opened new areas for technical development and growth. ■

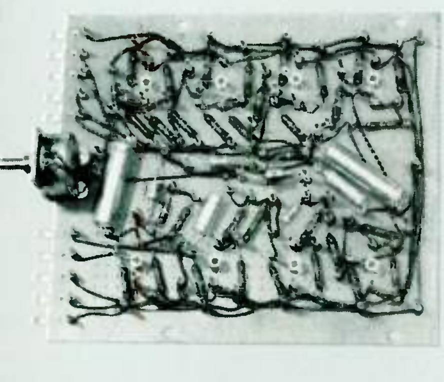


Fig. 1 (left)—The Static Slipsyn starter consists of three functional blocks of circuitry: the synchronizing circuit, the pull-out protection circuit, and the damper-winding protection circuit.

Fig. 2 (above)—View of the synchronizing module. The wire-wrap technique simplifies replacement of defective parts, and increases resistance to vibration.

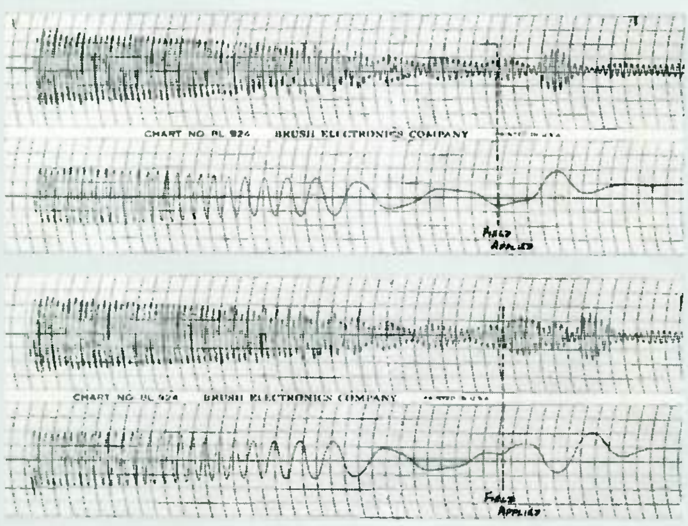


Fig. 3—Prior to synchronization, the magnetic poles of the stator are rotating faster than the rotor poles. The rotor can only be synchronized when like rotor and stator poles are receding from each other. If the field is applied before this time (**top**), the rotor can be accelerated to synchronous speed. If applied during recession (**bottom**), the rotor does not have enough time to accelerate, and the poles slip by each other—this can produce severe electrical and mechanical transients. Synchronization will not occur until like poles are again in recession.

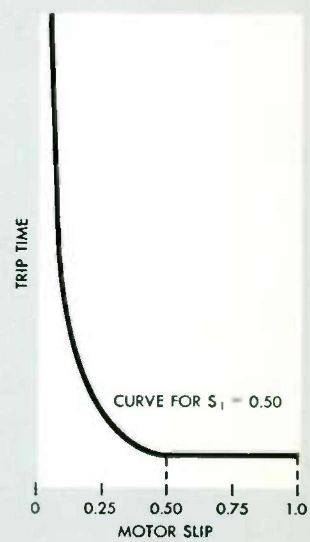


Fig. 4—By varying S_1, the operating curve for damper-winding protection can be made to match the design constants of a particular machine.

NEW DIMENSIONS IN SOUND . . . VIA A SINGLE A-

This new system makes possible the broadcast of two-signal stereophonic sound over a single a-m channel by simultaneous amplitude and frequency modulation of the carrier.

H. E. SWEENEY
Television-Radio Division
Westinghouse Electric Corp.
Metuchen, New Jersey

C. W. BAUGH, JR.
WASP
Westinghouse Electric Corp.
Drexel Hill, Pennsylvania

Stereophonic sound—sound with true spatial dimension—is creating a new interest in both a-m and f-m radio. As with the introduction of high-fidelity equipment a few years ago, stereophonic sound has been largely spurred by recent developments in recording techniques.

Many methods of stereophonic broadcasting are under investigation. Most of the methods that have been tried on the air are dual-channel systems—two separate broadcasting channels are required, such as am and fm, fm and fm, or tv and am or fm. In effect, the signals from a right-hand microphone are broadcast on one channel, and the signals from a left-hand microphone are broadcast on the other. When these separate signals are recreated in the a-m and f-m receiving sets, spaced some distance apart, the reproduced sound assumes the depth and direction that it had in the recording stage or studio.

However, these dual-channel systems have two major disadvantages: from the broadcaster's standpoint, two outlets are consumed by a single program; and from the listener's standpoint, the systems are not entirely compatible. If the listener tunes on only one channel, he will not receive a truly balanced monophonic signal.

The ideal in a stereophonic broadcast system is to provide a stereophonic signal that is completely compatible and that transmits a minimum of information necessary for good stereo presentation. Complete compatibility means not only that a stereo signal may be heard monophonically on a conventional receiver with the minimum degradation, but that a conventional radio signal may be heard monophonically on a stereo receiver. The Westinghouse system approaches this ideal.

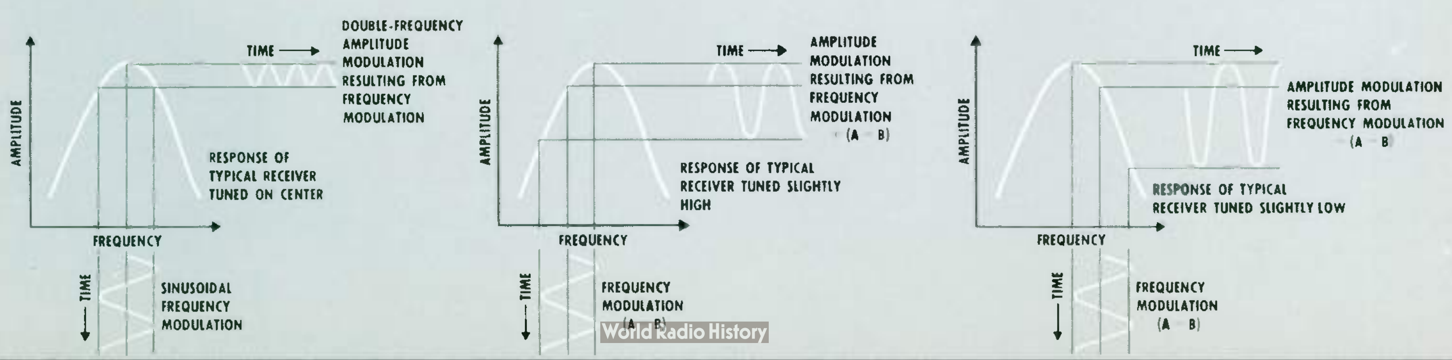
Two separate information channels, necessary for stereophonic transmission and reproduction, are broadcast by simultaneous amplitude and frequency modulation of the standard broadcast band carrier. The *amplitude* of the carrier is modulated with the sum of the signals from the left and right microphones, $(L + R)$. The *frequency* of the carrier is modulated with difference between the two signals, $(L - R)$. This difference signal is limited to the frequency range of 300 to 3000 cps and contains the stereophonic information.

A specially designed stereophonic receiver will recombine the $(L + R)$ information at its a-m detector with the $(L - R)$ information at its f-m detector in a simple algebraic manner:

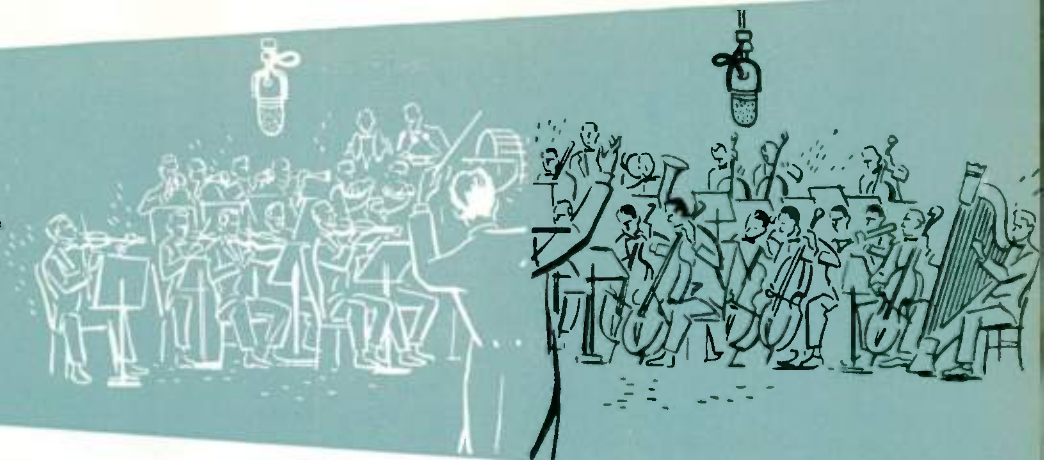
$$(L + R) + (L - R) = 2L$$
$$(L + R) - (L - R) = 2R$$

The L and R signals are applied to the two speakers.

A conventional receiver, tuned to the center of the band and having only an a-m detector, will reproduce only $(L + R)$, which is a balanced monophonic program. Furthermore, a stereophonic receiver, tuned to a conventional radio signal



ROADCAST CHANNEL



that has no f-m information, will produce identical sounds on both of its speakers.

An interesting additional feature of the Westinghouse a-m stereo system is that two standard a-m radio receivers, carefully tuned—one slightly on the low side of the a-m channel and the other slightly on the high side—can also provide separation of the L and R signals, and thus produce stereophonic sound.

The new system is compatible with present Federal Communications Commission's standards for a-m broadcasting. The amplitude modulation is essentially that of the normal broadcast band signal; the essential stereophonic information, supplied by varying the carrier frequency, is within the allotted 10-kc channel bandwidth, thereby preventing interference with adjacent a-m channels.

Westinghouse a-m stereo system specifications

A set of specifications were developed for the proposed a-m/f-m signal:

1. The signal carrier shall be both amplitude and frequency modulated.
2. The amplitude modulation is predominantly proportional to the algebraic sum of the two stereophonic signals (L-left microphone$+R$-right microphone) but includes a smaller signal that is a function of the stereophonic difference signal ($L-R$). This function is developed by a compensating system.
3. The maximum amplitude modulation shall be limited to 95 percent.
4. The frequency modulation shall be from the components of the stereophonic difference signals between 300 and 3000 cycles per second. The filter cut-off rate shall be 6 decibels per octave. The maximum deviation shall be 3 kilocycles.
5. When only one stereophonic signal exists, the maximum instantaneous amplitude shall occur simultaneously with the maximum instantaneous frequency deviation of the transmitted signal.

compensating system

Since the average a-m broadcast receiver has frequency-selective circuits (signal amplification is a function of frequency), the frequency modulated carrier produces some amplitude modulation, or "cross-talk" (Fig.1a). Furthermore, since for a center-tuned receiver, the resulting amplitude modulation will be predominantly the second harmonic of the original frequency modulation, the effect is actually worse than simple cross-talk, because it introduces harmonic distortion, both in stereophonic and monophonic receivers. Therefore, a *compensating* system is needed to precorrect the transmitted signal for the average receiver i-f passband. Because passbands of receivers vary widely, only partial compensation can be expected in many receivers, but this has been found satisfactory.

Fig. 1—(a) Because of the i-f response of a-m radio receivers, double-frequency amplitude modulation would result from frequency modulation if no precompensator were used at the transmitter. (b) Slope detection enables a standard a-m receiver to add or subtract the f-m signal from the a-m signal. If the receiver is tuned high, the f-m signal is added to the a-m signal; (c) if the receiver is tuned low, the f-m signal is subtracted from the a-m signal.

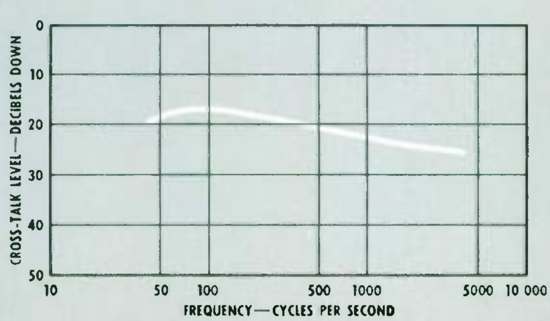


Fig. 2—Test measurement of the cross-talk of frequency modulation into the a-m channel

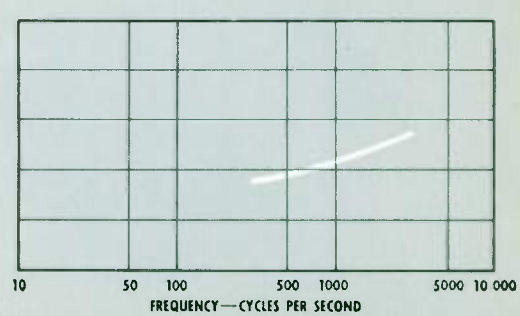


Fig. 3—Test measurement of the cross-talk of amplitude modulation into the f-m channel

Precompensation can be accomplished with a "notch filter," which has a frequency response that is the inverse of the average receiver passband over the bandwidth to be corrected. Frequency modulation of the oscillator ($L-R$ modulation) causes the signal to sweep across the notch filter response. Hence, the envelope of the signal leaving the notch filter is precorrected so that f-m cross-talk in the a-m channel of the receiver with an average i-f passband is effectively canceled. When $L+R$ is zero, the envelope of the signal at the antenna has the same shape as the envelope of the signal at the output of the notch filter. When $L+R$ is not zero, the envelope at the antennas has approximately the shape of the sum of phase-corrected $(L+R)$ and the phase-corrected envelope of the output of the notch filter.

A phase-corrector network is used to equalize the audio phase shift so that the frequency modulation and the precorrection envelope modulation are coincident in the radiated signal. A second phase corrector is used to put the $(L+R)$ modulation in time coincidence with the $(L-R)$ modulation in the radiated signal.

A measurement of the cross-talk of the frequency modulation into the a-m channel is shown in Fig. 2. Conversely, a measurement of the cross-talk of amplitude modulation into the f-m channel is shown in Fig. 3. Cross-talk of about 20 db down is usually considered sufficient separation for stereophonic purposes, where the signals in the two channels are not completely distinct.

transmitter

A block diagram of the complete transmitter is shown in Fig. 4. Neglecting the compensation system, the signal is generated in a straightforward manner. A source of frequency-modulated signal capable of 3-kc deviation at the broadcast frequency is required. This frequency-modulated carrier is the r-f drive for the power amplifier.

The audio frequency bandwidth of the f-m unit $(L-R)$ is limited to 300 to 3000 cps. No changes are necessary in the existing power stages of the transmitter if the frequency response of the amplifier stages is at least 5 kc with good phase response. The amplitude modulation is straightforward, and is no different than in standard practice except for the amplitude limitation of 95 percent, as opposed to a full 100 percent allowed in normal a-m broadcasting. This maximum allowable amplitude modulation is largely determined by economical receiver design. The modulation limit sets the minimum signal level that must be handled by the frequency detection system of the receiver. A maximum transmitter amplitude modulation of 95 percent will not place a severe requirement on the gain required in the f-m channel of the receiver, and is high enough to cause only a small reduction in transmitter coverage.

The frequency response of the amplitude modulation system can be as wide as allowed by FCC standards but should be no narrower than 3 kc for good stereo performance.

The only unusual block in the transmitter diagram is the notch filter, or precompensator. The notch filter can also be placed in the main r-f line at the point where the output of the filter feeds both the envelope detector and the r-f amplifier. This arrangement has the advantage of requiring less delay correction, but puts another unit in the main r-f line.

Monitor equipment is necessary to check the f-m deviation and the compensation system. Both of these functions can be checked with a stable receiver that is aligned to have an "average" passband.

The broadcast transmitter limiters or volume compressors should be modified to limit the L and R signals proportionately. Any gain change in one should be accompanied by the same change in the other to preserve balanced stereo information.

stereo receiver

A block diagram of a stereo receiver is shown in Fig. 5. The receiver has a conventional envelope detector for the $L+R$ a-m signal, and an f-m detector for the $L-R$ signal. Several refinements in receiver design have been made. For f-m detection, the signal is first amplitude-limited to a constant value. Because of the 95-percent a-m modulation of the

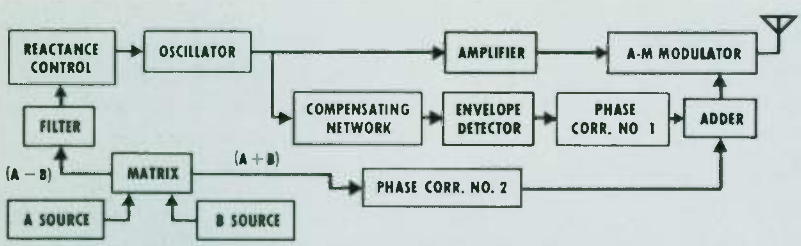


Fig. 4—Block diagram of a-m stereo transmitter.

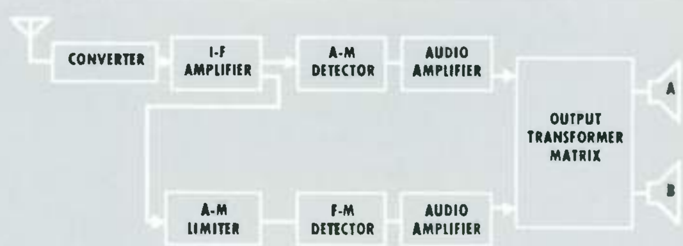
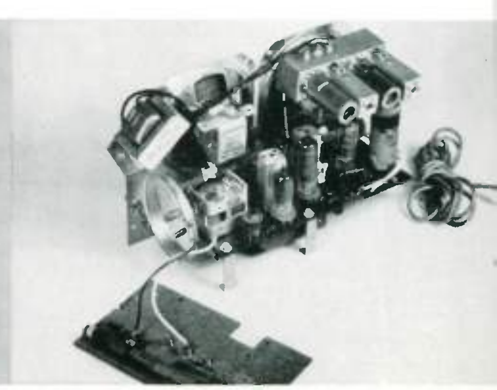


Fig. 5—Block diagram of a-m stereo receiver.



Comprehensive laboratory tests were made of the Westinghouse a-m stereo system.

carrier, the amplitude rejection capabilities of the f-m section are extremely important.

For ultimate stereophonic performance, the a-m and f-m signals should be balanced for both weak and strong signals. This requires a much more sensitive automatic gain control system than needed in conventional a-m receivers.

The master gain control is a ganged pair of potentiometers, one in each audio channel. The balance control is in the $L-R$ channel. When it is set at zero, there is no stereo information. As the $(L-R)$ component is increased, separation of the two channels is effected.

Two systems of matrixing the sum-and-difference signals to recover L and R channels have been tried. Transformer matrixing (Fig. 6a) has the advantage of simplicity. The output windings should deliver balanced L and R signals over the stereo bandwidth of 300 to 3000 cps. A phase splitter triode (Fig. 6b) with a resistive matrix is another method of obtaining a well-balanced output.

two-receiver method

As previously mentioned, a standard a-m receiver, when tuned to the center of the carrier signal, will produce a balanced monophonic signal, $(L+R)$. However, when a receiver is slightly side tuned, slope detection of the f-m signal $(L-R)$ takes place in combination with amplitude detection of the $(L+R)$ signal. If the receiver is tuned high (Fig. 1b), slope detection will add some of the $(L-R)$ signal to the $(L+R)$ amplitude signal to produce a composite signal predominantly L. A second receiver tuned slightly low (Fig. 1c) reverses the phase of the $(L-R)$ component to produce a signal predominantly R. Using this technique, good quality stereo can be produced from two unmodified broadcast receivers.

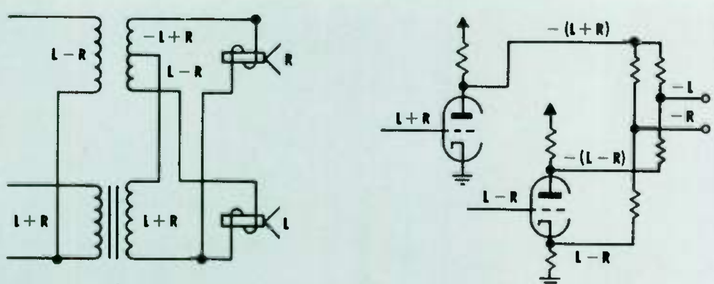
stereo tests

A number of compatible stereo systems have already been announced, and more are being developed. As a result, an all-industry National Stereophonic-Radio Committee has been formed by the Electronic Industries Association. The committee's purpose is to study the various transmission systems and to advise the Federal Communications Commission on the characteristics of each.

Westinghouse pioneer radio station KDKA, in Pittsburgh, has already conducted a number of stereophonic test broadcasts. With FCC permission, KDKA is presently preparing to test the a-m/f-m duplex system described in this article. The results of all these tests are being filed with the FCC.

These latest tests will give both the listener and the broadcaster a chance to evaluate the advantages of the Westinghouse a-m stereo system. Only minor modifications are required in the transmitter to broadcast stereo information. Stereo receivers required for this system are relatively simple and inexpensive. Stereo reception using two ordinary a-m receivers is also being evaluated. During these tests, no degradation of the program will result for the listener using a single broadcast receiver. ■

Radio station KDKA first began dual-channel stereophonic a-m and f-m broadcasts in November, 1957. KDKA made further tests to evaluate other systems of stereophonic sound transmission in cooperation with the Federal Communications Commission in March, 1959. A panel of representative citizens—housewives, businessmen, musicians, and others—were assembled to hear demonstrations of various stereo transmission systems. In addition to the two separate channel a-m/f-m system, an f-m/f-m sub-channel multiplex type operation was demonstrated. Multiplex operation is the simultaneous transmission of two signals on a single f-m carrier. A standard f-m receiver will receive one of the signals, but a special receiver is required to recover the second signal. KDKA has been using this type of multiplex operation since June, 1958, but for another purpose—the simultaneous transmission of music programming of regular f-m and baseball broadcasts to network stations through the multiplexed signal.

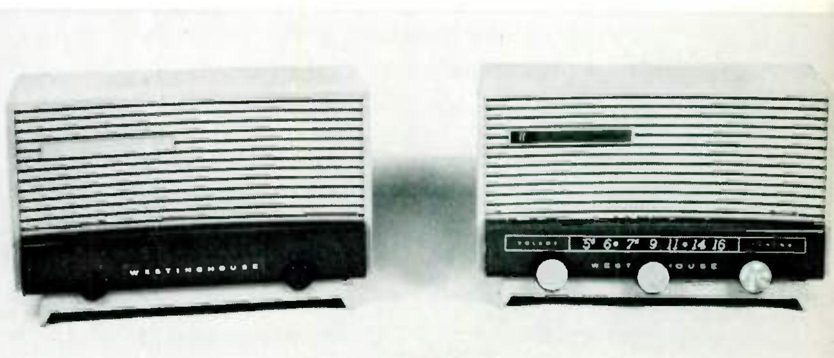


6a 6b

Fig. 6—Two methods of matrixing the sum-and-difference signals at the receiver: (**a**) Output transformer matrixing is used in a receiver designed by Westinghouse engineers. The $(L—R)$ transformer has a tapped secondary. One half is tied to the $(L+R)$ secondary and the result is $(L+R)+(L—R)=2L$. The second half is inverted to produce $(L+R)—(L—R)=2R$. (**b**) Matrixing can also be accomplished electronically with the phase-splitter triode and resistive matrix arrangement.

Left—Chassis of experimental stereo receiver. The limiter and f-m detector stages are shown on the small chassis in the upper right of the main chassis.

Right—External view of experimental stereo receiver. The cabinet at the far right contains the receiver chassis; the cabinet at the near right contains only a matched speaker system. The main volume control is on the left, the tuning control is on the right, and the stereo balance control is in the center of the receiver cabinet.



Right—Luxury, excitement, and a view of Miami are all part of an elevator that serves the Ivory Tower, a nightclub atop the Saxony Hotel in Miami.

The glass-enclosed car can transport 33 guests from the lobby to the Ivory Tower. As the elevator doors close at the start of the ride, the ceiling lights dim, giving a pin-point effect. A built-in, 2-ton air conditioner keeps the passengers cool, an oriental carpet cushions their feet, and soft music fills the cab.

The high point of the ride is the seven-mile view of Miami from the glass-enclosed cab. And the leisurely rise of 100 feet per minute allows enough time to enjoy it.

Below—Several novel features have been incorporated in this experimental aluminum tank for pole-type distribution transformers, but the most significant are the extruded-aluminum fin-like sections, which are made in a variety of shapes for different purposes. Some fins are deep, thin sections for cooling; others are shallow and wider, for bolting internal parts in place; still others are heavy, parallel ribs, to provide a lifting slot on the outer wall.

WHAT'S NEW IN ENGINEERING

HIGH-TEMPERATURE THERMOELECTRIC MATERIAL

A new thermoelectric material has been developed—the most efficient of its type yet discovered—for use in the temperature range from 850 to 1500 degrees F. This top temperature is well above the melting point of aluminum, magnesium, and many common thermoelectric materials.

The new semiconductor material—designed solely for thermoelectric purposes—is a three-element compound known as indium arsenide phosphide. It is prepared by chemically combining high-purity indium, arsenic, and phosphorus.

The new material fills a gap in the substances that have been available for thermoelectric power generation. Many semiconductors lose their thermoelectric properties, or even decompose, before reaching temperatures needed for effective power-producing devices.

Types of thermoelectric substances now being investigated fall into three main categories: semiconductors, metallic compositions, and mixed-valence compounds. All three groups of materials are expected to find use in thermoelectric power generation. But of all classes of thermoelectric materials, semiconductors possess, to a unique degree, the major properties of a good thermoelectric material. These properties include the ability to generate a reasonable voltage with application of heat (high thermoelectric power), the ability to produce an electric current without high internal losses (low electrical resistance), and the ability to maintain a difference in temperature when heated (low heat conductivity). ■

FLUORESCENT LAMP USES ORDINARY LIGHT SOCKET

An experimental fluorescent lamp that requires no external ballast or starter can be installed in an ordinary light socket

(see right). The lamp contains a built-in bi-metal starting switch similar to that used in a fluorescent starter. In addition, the new lamp contains an incandescent filament, which eliminates the large external inductor ballast in use today.

The use of the internal incandescent filament results in other important advantages. First, the incandescent filament emits light, adding to the total lumen output of the lamp. Secondly, the color of the light produced by the tungsten filament, in the red end of the spectrum, augments the light of efficient fluorescent phosphors, which is in the blue-green end of the spectrum. However, the self-ballasted fluorescent lamps have far greater efficiency and several times the life of ordinary incandescent lamps.

The lamp can be made in either the conventional double-ended variety or with the socket on a single end. In addition, various decorative shapes are possible. ▪

CAPACITOR POTENTIAL INDICATOR

A new capacitor potential indicator for high-voltage transmission lines up to 345 kv can be used for unattended substation potential indication, automatic "throwover" initiation, potential indication during maintenance, and as a source for oscillograph records. Future designs will allow the use of the capacitor potential indicator at voltages up to 750 kv.

The unit consists of a high-voltage capacitor rated line-to-line and connected line-to-ground. In series with the ground connection is a hermetically sealed, single-pole double-throw, plug-in current relay. This relay responds to the capacitor current, which is a function of the line-to-ground voltage. The relay is very sensitive and can be set to respond to different levels of voltage. Also, the relay closes its contacts whenever the line is energized. These contacts can then be used to sound alarms or initiate any applicable function.

With a slight modification, the device can be used as a coupling capacitor for carrier-current application concurrent with potential indication.

Basic sources of potential in the past have been potential transformers and coupling capacitor potential devices. Where any appreciable burden is to be connected, or relaying or metering energy is desired, these devices must still be used. ▪

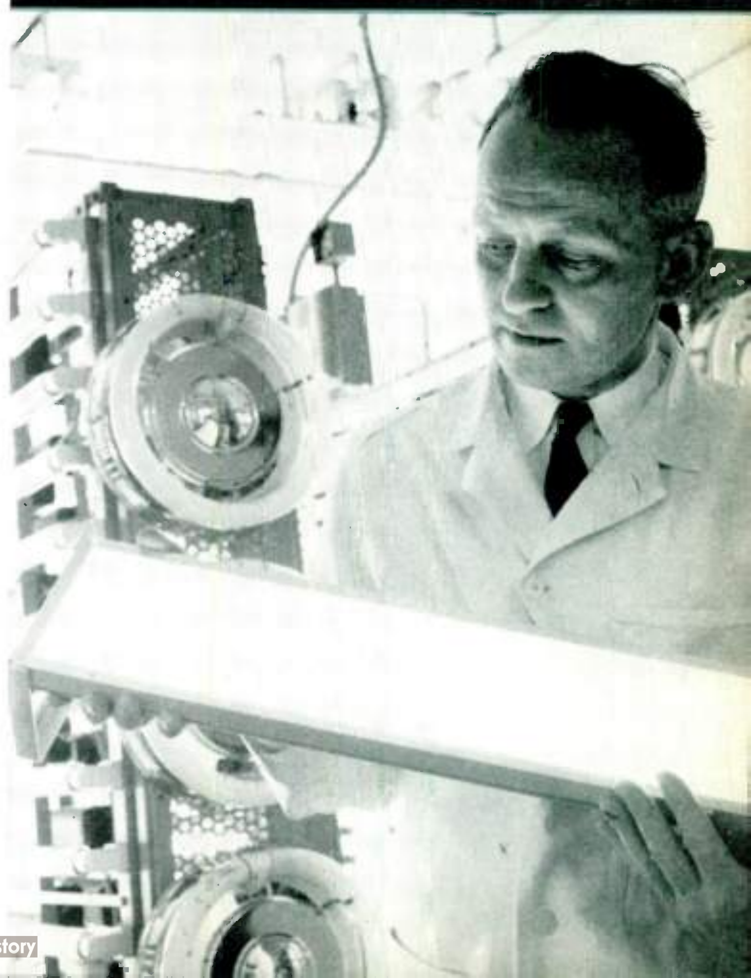
A WIDE, THIN, FLAT FLUORESCENT LAMP

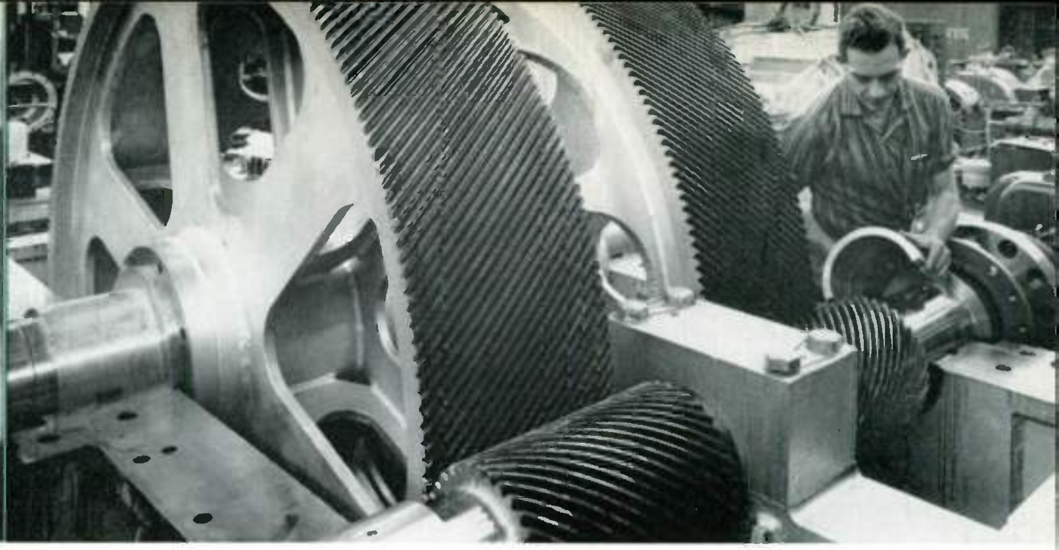
A new development in fluorescent lighting has led to fluorescent lamps that resemble large glass tiles. They produce fluorescent light when an arc or electric discharge traverses the labyrinth sealed within the glass.

Experimental models of this labyrinth lamp are being produced in various sizes. One laboratory model is 24 inches long, 8 inches wide, and 1 inch thick; another is 12 inches square and 1 inch thick. One model **(see right)** has a reflector on one surface that reflects all the light through the opposite surface. Also pattern glass, mounted on one surface, controls the brightness and direction of the light.

Since labyrinth-type lamps can be square or rectangular, they could be used to form blocks of light in walls, ceilings, or floors. Because of their thinness, they can reduce drastically the depth of ceiling required for lamp mounting. They also can be made of heavy, shock-resisting glass, and might be used in roadways, landing strips, and similar applications.

The lamp should also reduce maintenance costs. In existing fluorescent fixtures, the fluorescent tubes, the reflector and, when present, the diffusing element must be cleaned; in the labyrinthian lamp, these three elements are integral, and only the outer glass surface of the lamp must be cleaned. ▪





LAMPS PRINT LETTERS, NUMERALS, AND SYMBOLS

A new method for the display of numerical and verbal information has resulted from the development of plug-in electroluminescent readout lamps—thin, flat, light-emitting plates about the size of playing cards. Two forms of readout lamps have been made: the first—known as Alpha lamps—register all letters in the alphabet, numerals from 0 through 9, plus and minus signs, and many symbols **(see above)**; the second—termed Numeric lamps—register 16 letters, numerals from 0 through 9, and plus or minus symbols.

The lamps can be used in applications for measurement and instrumentation, or as information display boards similar to those found in stock exchanges, air and rail terminals, and military information and command centers. One contemplated application uses an array of readout lamps to display continuously changing depth soundings aboard ship. Another, from the steel industry, uses three separated arrays of readout lamps to notify personnel of production requirements and characteristics of each ingot in process through a rolling mill.

The devices are ideally suited for information display applications because of their high reliability. Since electroluminescent light is produced by exciting a film of phosphor with an alternating field, the readout lamps age but do not fail. New lamps can be plugged in whenever intensity declines to an inadequate level after a life of 3000 hours.

Because the numbers and letters are a two-dimensional outline of light, they are free of distortion or shadowing. Characters $2\frac{3}{4}$ inches high can be read from 50 feet with ambient lighting of 50 footcandles at the viewer's position.

The lamps require little space. Up to 100 characters, $1\frac{3}{8}$ inches high, can be displayed in three square feet of panel area; 100 characters, $2\frac{3}{4}$ inches high, require about 9 square feet. Both lamp sizes can be plugged in a standard flat socket; the lamps and socket are less than one inch thick.

The lamps can be supplied with 240 or 460 volts at frequencies from 60 to 400 cycles per second, and almost any transformer or power source affording these voltages can be used. For high intensity output and greater visibility, 400-cycle transistorized power packs can be used.

Because the readout lamp requires little power—less than 0.2 watts for the largest size—conventional switching equipment can be used. Since lamp response is instantaneous, symbols can be substituted faster than the eye can function. ■

LARGEST SPEED INCREASER FOR PIPELINE SERVICE

The world's largest speed increaser is now driving a 15 000-hp compressor in natural gas pipeline service **(see above)**. The unusual size of the speed increaser caused several design problems. The high inertial starting torque was reduced to an operating minimum by reducing the gear diameter and at the same time increasing the gear face width to transmit the load. However, because of the wide gear face, a three-bearing pinion shaft was used to eliminate shaft deflection.

All bearings and gear mesh are lubricated by a forced-feed lubrication system. A three-section fabricated housing protects the gearing mechanically, provides permanent alignment, and insures stability of operation. Three air-to-oil fan-type coolers are used to cool the lubricating oil to eliminate water cooling requirements.

The unit is now running at the Egypt, Mississippi compressor station of the Texas Eastern Transmission Corporation. ■

SILICON SWITCH

A new silicon semiconductor device has been developed—a Trinistor triode, which is a three-terminal multi-junction NPNP switch whose breakover voltage can be controlled by a base current.

If no input signal is supplied to the base terminal, the device will block up to the full rated voltage in the forward or conducting direction. When a base signal of two to five volts is applied, the device will switch from a blocking to a conducting condition, characterized by a low forward drop similar to that of a conventional silicon diode. The base signal draws a current of 25 to 150 milliamperes. In the reverse direction, the Trinistor triode will block up to its rated voltage.

The Trinistor triode is suited to applications in circuits with voltages up to 400 volts and currents up to 50 amperes. In addition, it can turn on in 1.0 microsecond and turn off in 15 to 20 microseconds, depending on load current.

The Trinistor triode can be used in place of thyratrons with the advantages of lower forward drop, absence of a filament with its associated warm-up time, faster firing and recovery times, and better reliability. The Trinistor triode also can be used as a converter, an inverter, a frequency changer, a variable frequency generator, a motor controller, or a voltage regulator. In some instances, it can replace magnetic amplifiers, and high-power modulators. ■

PERSONALITY PROFILES

Since joining Westinghouse in 1937, **H. R. REESE** has worked continuously with steam turbines, mostly in their design. He worked as a design engineer in the thermodynamic, mechanical, development, and central-station design sections. His design work was interrupted during the war when he was made supervising steam service engineer in the Westinghouse Philadelphia Office. After the war, Reese returned to the central-station design section.

Reese almost retraced his steps through the various design sections in a management capacity. He served as assistant manager of the thermodynamic section, and then assistant manager of the central station section, before being appointed manager of the Large Turbine Advance Design Section in 1956, his present position. During this time, Reese has worked on some of the largest steam-turbine units ever built.

In this issue, **PAUL O. GADDIS** takes a searching look at the role of a relatively new breed of management—the project manager in an advanced-technology industry. This is most apropos, since Gaddis occupies such a position himself, as a project manager of an advanced nuclear test facility.

For a young man, Gaddis has been active in a variety of different fields. He first undertook to gain an engineering education at California Institute of Technology in 1942. After a year, he won an appointment to the U.S. Naval Academy at Annapolis, from which he graduated in 1946 with a degree in marine engineering.

Early in 1954, Gaddis resigned from the Navy, and shortly thereafter joined Westinghouse, initially as a project engineer in atomic power activities. After several staff and line assignments, Gaddis was appointed project manager of an organization charged with the design, procurement of components, construction, and initial operation of a special facility, the position he now holds.

After four years in the Army during World War II, **A. S. DAVIS** was anxious to get on with his education; he graduated from Massachusetts Institute of Technology with a BSME three years later.

After graduation, he came to Westinghouse on the Graduate Student Training Course, and after a year of assignments at various divisions, he went to work for the Gearing Division. He started work as a sales correspondent, and two years later became the division's representative for the Atlantic and Southeastern Regions. After two years in this capacity, he traveled to the other end of the nation to become the division's representative for the Pacific Coast Region. In 1956, he became Manager of Gearing Product Sales.

Though his forte is selling gear units, he also helped develop the Moduline system.

H. W. LENSNER literally "grew up" with power-line carrier for relaying and telemetering applications. He joined Westinghouse on the Graduate Student Course in the fall of 1939, and has been in the relay section continuously since 1940. In 1951, Lensner was made a Senior Design Engineer responsible for high-speed relays for transmission-line protection, and for all pilot-channel relaying using wire, powerline carrier, or microwave channels. Lensner has accumulated thirteen U. S. patents, with several more pending, including one on a transistorized carrier relaying scheme.

Lensner attended Case Institute of Technology, receiving his BSEE in 1937, and his MSEE in 1939.

DEAN J. MACGREGOR graduated from the University of Michigan in 1950 with a BSME degree. One year later he added a degree in electrical engineering.

He joined Westinghouse on the Graduate Student Training Course, during which time he attended Electrical Design School and had assignments at several divisions. He settled down in the standard development section of the General Purpose Control Department and was soon working on development and manufacture of a-c contactors, relays, reduced-voltage starters, and other control devices.

In 1957, he was transferred to the long-range major development section, where he developed the static synchronous motor starter and is presently developing other semiconductor control devices.

RICHARD M. HAYFORD graduated from the University of Syracuse with a BSEE in 1951. He spent the next four years designing and testing automatic flight-control equipment. In June, 1955, he came with the General Purpose Control Department and started applying Cypak static controls to various industries. However, this job was sidetracked when he was called into the Army two months later. In 1957, he returned to the department, and again started work on application of Cypak controls. In 1958, he moved into another area of static control, helping develop the static synchronous motor starter.

C. W. BAUGH is a graduate of Ohio University with a BSEE in 1944. He added an MSEE from the California Institute of Technology in 1947, and immediately joined Westinghouse on the Graduate Student Course. His first assignment was in the Research Laboratories. In 1950, he was transferred to the Television and Radio Division to work in the advanced development laboratory. Here, he worked on color television receivers and systems, remote control for television receivers, and developed the Westinghouse automatic fine tuning system for television receivers. He was given a new assignment in the Westinghouse Advanced Systems Planning group in March 1959.

H. E. SWEENEY attended the University of Minnesota, and graduated from the University of Arizona with a BSEE in 1952. He came to Westinghouse on the Graduate Student Program, and was chosen for Design School. He was assigned to the advanced development laboratory of the Television and Radio Division in 1953, and since that time, has done extensive work on various color television and high-definition monochrome television systems. Sweeney received his MSEE from Rutgers University this year.

ELECTRICITY FROM SUNLIGHT

This experimental apparatus is used to generate electricity from the heat of the sun. The sun's rays, gathered by the large concave mirror on the right, are focused on a special assembly of thermoelectric materials, which convert the intense heat directly into electricity. Westinghouse research scientists are using the apparatus to study the feasibility of such a system for supplying the electric power requirements of space vehicles of the future.